European Commission

Methodology

for the Analysis of Solid Waste (SWA-Tool)

User Version

Project:	**SWA-Tool, Development of a Methodological Tool to Enhance the Precision & Comparability of Solid Waste Analysis Data**
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Project Coordinator:	**iC consulenten ZT GmbH, Austria**

Contractors:	iC consulenten ZT GmbH	Austria
	City Council of Vienna, MA 48	Austria
	Technical University Berlin	Germany
	University of Northumbria	UK
	Gruppo Impresa Finance srl	Italy
	Fundacion Gaiker	Spain
	ICIM	Romania
	Oil and Gas Institute	Poland
	Newcastle City Council	UK
	ASM Brescia spa	Italy
	City of Bilbao	Spain
	COMPREST	Romania
	City of Cracow	Poland

Contact: iC consulenten ZT GmbH, DI Gertraud Moser, Kaiserstrasse 45, A-1070 Vienna
Phone: +43 (1) 521 69-291, email: g.moser@ic-vienna.at; www.ic-vienna.at

Information available: www.wastesolutions.org
www.swa-tool.net

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C.I.	Confidence interval
Dev.	Deviation
GNP	Gross National Product
kg	Kilogram
l	Litres
m	Metre
m³	Cubic metre
mm	Millimetre
n	Number of sampling units
RCV	Refuse Collection Vehicle
SWA-Tool	Solid Waste Analysis Tool
VarCoeff	Variation Coefficient

1. INTRODUCTION

This report will present a standardised methodology for the analysis of 'solid waste'. It has been developed as part of the European Commission Fifth Framework, 'Solid Waste Analysis Tool' (SWA-Tool) project.

The SWA-Tool aims to provide a waste analysis methodology for use at a local and regional level. It is therefore necessary to determine the information needs of the areas under investigation, including monitoring and reporting requirements necessary for effective waste management at these levels.
These local and regional needs, however, also operate within a wider framework of various regional, national, European Union or even international waste management requirements. The SWA-Tool methodology should take account of these wider requirements wherever possible in order to optimise synergy and relevance between the local and regional level and these wider levels.

The SWA-Tool does not aim to cover all municipal solid waste streams. It is therefore important to distinguish the scope of waste to be included as the parent population (whole quantity of waste in the survey area) within this methodology.
In the framework of this project municipal solid waste may be waste, which is collected by or on behalf of a municipality, via pick-up systems and/or drop-off systems depending on the municipality and the country. Such waste may derive from households, commerce, and industry and from municipality activities such as street cleaning or maintaining green spaces. As the collections system may differ for various communities municipal solid waste does not necessarily include the same categories of materials everywhere.

The methodology describes an approach for the representative sampling of the 'residual solid waste'[1] fraction of that portion of municipal solid waste described as "daily household and commercial waste"[2]. It also includes an approach for the manual sorting and analysis of such waste to determine the following:

1. Waste Characterisation (composition)

2. Waste Quantification (amount produced) based on waste composition

The methodology will establish minimum standards, which a waste analysis should always meet such as: sorting procedures; sorting categories; definition of statistical accuracy and common reporting guidelines. This will enable the comparability of results between different waste analyses.
In addition, different waste management regimes may operate at a local or regional level. A key aspect of the SWA-Tool methodology is that it should be capable of adaptation to differing local circumstances. The methodology will therefore provide additional criteria beyond the minimum standards to enable the user to select the most appropriate analysis design in relation to their specific local objectives and circumstances.

[1] Residual solid waste is mixed solid waste from households and includes similar commercial mixed solid waste, which is co-collected.
[2] As defined by the European Environmental Agency (EEA) report "Household and municipal waste: Comparability of data in EEA member countries" (2000) www.eea.eu.int

Chapter 2 is concerned with the definition of relevant waste terminology, the scope of waste to be considered and the overall statistical standards for a waste analysis. In addition an important part of the SWA-Tool project is the development of a standard system of waste classification (Annex 1); at present there is no standard system of waste terminology and waste category classifications for use in a solid waste analysis within the European Union. Chapter 3 describes the methodology for waste characterisation and waste quantification.

Besides the “user version” there is also a “long version” of the methodology available on the websites mentioned on the cover sheet. In some points the user version refers to the long version.

2. DEFINITIONS

2.1 WASTE TERMINOLOGY AND SCOPE

The actual constitution of municipal waste varies between municipalities across the European Union. However, the fraction of municipal solid waste defined as **"daily household and commercial waste"** which forms the scope of waste to be covered by the SWA-Tool methodology includes:

- **Residual household waste** which may be described as mixed solid waste from households, which is collected, transported, and disposed of, either by the household, the municipality or by any other third party in any kind of containers and/ or plastic bags; and

- **Residual co-collected commercial waste** which may be described as mixed solid waste from commerce, which is co-collected, transported, and co-disposed of, either by the household, the municipality or by any other third party in any kind of containers and/ or plastic bags. The composition of daily residual commercial waste is similar to the composition of residual waste from households. But the amount and composition arises in spatial clusters and depending on the business sector.

Not included in this kind of definition are:

- Separately collected household and commercial material streams such as glass, paper, plastics;

- Separately collected municipal waste streams which may include small scale hazardous waste, electrical/electronic waste, street cleanings, garden/park waste;

- Any other waste stream, which is not produced from routine activity such as bulky waste.

2.2 STATISTICAL STANDARDS

As it is impossible to analyse the whole quantity of waste in a survey area (parent population), a **sample** (random sample) has to be taken. This sample has to be **representative** for the area of investigation and should describe the characteristics of the whole parent population. The consistency of household/commercial waste is varied i.e. heterogeneous consisting of many different components or categories. Furthermore the size of waste particles ranges from mm (fine elements) up to 1 m (e.g. parts of furniture). In order to obtain statistically acceptable results for such heterogeneous conditions it is necessary to analyse a suitable sample size.

A key objective of this methodology is to enable waste analyses to achieve results at or above a minimum statistical accuracy in a cost effective way.
The minimum **statistical standards** demanded by the methodology are defined as follows:

Recommendation 1

Results shall be expressed on a 95 % confidence level

The value of relative accuracy of the total result (weight of the sampling units) shall be **below 10 %** (maximum allowance for random sampling error for the total results)

The value of relative accuracy for the predominant categories (organic, paper and cardboard, plastic, glass, metal and fines) shall be **below 20 %** (maximum allowance for random sampling error)

A more detailed explanation of the statistical background to the above standards is contained in Annex 2: Statistical Background.

3. WASTE CHARACTERISATION

An essential component of a waste analysis involves waste characterisation or the determination of waste composition. There are four recommended stages to waste characterisation as follows:

1. **Pre-Investigation**
2. **Analysis Design and Planning**
3. **Execution of Waste Analysis**
4. **Evaluation of Waste Analysis**

3.1 PRE-INVESTIGATION

The pre-investigation stage is concerned with the provision of necessary background information for the municipality, county or country intending to undertake a waste analysis. This should form the basis of the subsequent waste analysis planning stage where appropriate. It also provides some of the background necessary for an effective evaluation of the outcomes of a waste analysis.

3.1.1 Background Information

Recommendation 2

It is **not** recommended to collect all below mentioned data. Only data shall be collected which are important for the creation of a selection basis and which are needed to create the analysis design. This is very country specific and also might vary from case to case.

The following background information to a waste analysis is suggested:

1. General Description of the Area Under Investigation

A general overview of the area under investigation and the portion of the area to be involved in the waste analysis is recommended to provide a useful background context to the proposed study and assist in the planning stage. The following minimum information is suggested:

(i) Identification of the area or portion of the area to be assessed, its location and surface area;
(ii) Identification of the various relevant geo-political districts and the levels at which relevant waste management data may be available.

2. General Population Information and Waste Management Information

General population information and waste management information is necessary to create a selection basis from which the representative sample can be generated. Therefore it becomes necessary to evaluate the factors which could influence the composition of waste in order to know which data have to be collected.

The following data could be important to collect:

General Population Information

(i) Number of inhabitants
(ii) Number of households
(iii) Income (such as GNP per capita)
(iv) Types and proportions of residential structures

Waste Management Information

(i) General description of the organisation of the waste management system (actors, responsibilities etc.)
(ii) Type of waste streams produced and collected especially mixed residual household, and co-collected household and commercial waste
(iii) Description of waste container systems in use such as household bins, communal bins and bin storage capacities
(iv) Average numbers of households and/or persons using bins
(v) Total bin volume; spatial distribution of bins; collection intervals
(vi) Method of waste collection such as open truck or refuse collection vehicles compactor and types of waste collected
(vii) Description of collection rounds
(viii) Weighing data of collection vehicles
(ix) Disposal methods such as landfill, energy from waste, reuse/recycling and the types of waste and quantities involved.

3.1.2 Stratification

Stratification is the statistical subdivision of the in-homogenous parent population (e.g. waste arising of an area) into (more) homogenous sub populations (non overlapping groups, e.g. waste from a certain residential structure), called strata.

The variation within strata is usually smaller than the overall population variance. This causes two effects:

- A statistical **stratification increases the accuracy of results** at a given sample size
  or
- a statistical **stratification** allows to **reduce the sample size** to reach an **aspired level of accuracy**

In waste analyses the main objective of stratification usually is to obtain specific results for single sub populations (e.g. waste from areas with gardening, waste from multi storey buildings, waste from different districts etc.). Here it is

considered that specific parameters might have an influence on waste composition or waste amount.
An essential prerequisite is that the number of sampling units for each stratum is adequate to obtain reliable results of a certain accuracy for each stratum.

A "waste management stratification" aims at accurate results for sub populations. Thus, the required number of sampling units has to be much larger than in case of a statistical stratification which usually aims at the improvement of accuracy of the total result of a waste analysis.

Recommendation 3

Generally, a stratification is not compulsory for a waste analysis program, but may have advantages for both, accuracy of results and additional waste management information.

Potential Stratification Criteria

A large number of factors may influence the composition or the amount of waste to be analysed and these may in turn vary in effect between municipalities; examples include:

- Residential structure
- Heating systems
- Seasonal variations
- Bin size
- Availability of civic amenity sites
- Holiday periods
- Type of collection system (separate collection)
- Levels of public education and awareness on waste issues
- Etc.

An important aspect of the SWA-Tool methodology is to provide the users with sufficient information to enable them to determine which if any stratification criteria should be incorporated in their waste analysis design. This will also depend on the purpose of the waste analysis and the waste management conditions within the area of investigation.

Within the SWA-Tool project, a statistical analysis of data from past waste analyses within several cities and areas in Europe has been undertaken. The results of this investigation show that in some cases the applied strata did not demonstrate any statistical significance with regard to their impact on waste composition. However, based on this evaluation a number of stratification criteria may indeed have a significant influence on waste composition and could therefore form a useful part of a municipal waste analysis program:

Table 1 Stratification Criteria

Stratification Criteria	Recommendation	Notes
Seasonality	Stratification according to seasons **shall always be considered**. Generally, a seasonal waste analysis should be done based on a minimum of three and ideally four, seasonal sorting campaigns. Since waste analysis results tend to be similar for spring and autumn, one of these two seasons may be left out.	Household and commercial waste may be subject to significant seasonal variations in quantity and composition.
Residential Structure	Generally, waste analysis stratification according to different residential structures and their locations **can be recommended**.	The following types of residential structures and locations have been demonstrated to act as significant stratification criteria: • Rural areas • Suburban areas • Inner city areas • Multiple dwellings • Multi storey buildings
Bin Size	Generally, waste analysis stratification according to the following bin sizes **can be recommended**: • Bins up to 240 litres volume • Bins above 240 litres volume	
Collection System	It has **not been possible to provide definitive recommendations** for potential stratification criteria based on different waste collection systems.	However it is reasonable to assume that there may be significant differences in waste composition between areas with and without separate collection of recyclables. Therefore, assuming it is possible to delineate those areas with and without separate collection of recyclables this may be a potentially useful stratification criterion.
Source of Waste (Household or Commercial Waste)	Generally, stratification according to the source of waste as either household waste or commercial waste **is recommended** where possible.	In most cases, waste from areas with commercial activities is significantly different to waste from residential areas.
Socio-economic Influences	It has **not been possible to provide definitive recommendations** for potential stratification criteria based on different socio-economic influences. However, these may be reflected within the criterion residential structure. A municipality may consider investigating these influences should sufficient planning information and resources be available.	
Collection Day	Where a daily collection (excluding weekends) of all relevant waste is undertaken, it may be useful to compare the variation of waste amounts according to days of the week. In those cases where such waste data or operational information suggests a significant difference between waste composition/arisings between different days of the week, **it is recommended** these days be used as stratification criteria.	In some cities/regions all the waste bins are collected every weekday. In these instances waste composition and amounts are often significantly different on Mondays, which tend to include weekend waste, compared to the remaining days of the week. Potential strata could be Monday waste (including weekend waste) and another weekday (waste representative for the rest of the week).

3.2 ANALYSIS DESIGN AND PLANNING

3.2.1 Type of Sampling

The parent population for a waste analysis campaign is the whole quantity of residual household waste and/or residual co-collected commercial waste, which may be sampled from and subsequently analysed. This may encompass the whole area of a municipality or a defined part of a municipality although the former will generally be the case in order to obtain waste analysis results, which are representative of the whole area under investigation. A sample refers to a subset of the parent population and it is necessary to work with waste samples because it is not possible to analyse the whole population of waste for the area under investigation.

Recommendation 4

It is recommended that stratified random sampling should be used, where possible, as the basis for sample selection for a local or regional waste analysis program. Whatever strata are chosen it is crucial that the relevant sources of waste to be sampled from, such as the waste bins, are capable of being attributed to, and sampled according to, the chosen strata.

For the theoretical background refer to “Methodology for the Analysis of Solid Waste (SWA-Tool) – Long Version”.

3.2.2 Number and Type of Strata

Generally, a **stratification is not compulsory** for a waste analysis program, but may have advantages for both accuracy of results and additional waste management information (refer to Chapter 3.1.2).

Ultimately the decision concerning the number and type of strata to use in a waste analysis depends on several factors including the waste management information needs of the municipality, the availability of adequate waste planning data and sufficient resources.

Recommendation 5

It is recommended that not more than 5 relevant strata shall be used. The use of more than 5 strata would result in an excessive number of necessary samples (larger sample size) in order to achieve the required accuracy of results for each stratum.

Examples of the SWA-Tool Project

An integral part of the SWA-Tool project has involved a demonstration phase where the draft waste analysis methodology has been implemented in five of the project's **Partner Cities**. Each Partner City has undertaken a waste analysis program, which was designed according to the draft methodology and the results of the evaluation of the stratification criteria whilst remaining appropriate to their local waste management circumstances. The number of waste analyses carried out and the stratification criteria used, varied between each of the cities.
Details of each City's waste analysis program are shown in Table 2 overleaf.

Table 2 Details of Partner Cities Waste Analysis Stratification Criteria

Partner City	Chosen Stratification Criteria	Seasonal Campaigns Undertaken
Bilbao	**Source of Waste** as represented by type of district: • Residential • Commercial/residential **Day of Week**: • Weekends (incl. Bank holidays) • Working Days	Summer Winter
Brasov	**Socio-Economic Status** of Residents as represented by: Residential Structure Type: • Single Dwellings • Multi-storey **Bin Size** Single Dwellings: • 120 litres • 240 litres **Bin Size** Multi-Storey: • 240 litres • 1100 litres	Spring Summer
Brescia	**Socio-economic Status** of Residents as represented by District Type: • Household Areas • Mixed Areas • Commercial Areas **Collection Weekday**: • Mondays • Rest of Week	Summer Winter Spring
Krakow	**Socio-Economic Status** of Residents as represented by: Residential Structure Type: • One family houses • Multi-storey **Collection Weekday**: • After Weekend (including waste of the weekend) • Before of Weekend	Spring Summer
Newcastle	**Socio-Economic Status** of Residents as represented by Local Authority Grading of Property Values. (Council Tax Bands): • Council Tax Band A and B (lowest value properties) • Council Tax Band "Others" (higher value properties combined)	Summer Winter Spring

In practical terms it will be useful to set up a **stratification matrix** at the initial planning stage. This matrix will show if the necessary data and information for a stratification are available. As an example the table below shows the distribution of inhabitants depending on three residential structures and two groups of bin size.

Table 3 Distribution of Inhabitants According to Stratification Criteria

Stratification Criteria	A Waste Bins <240 l	B Waste Bins >240 l
1 Suburban Areas	10%	5%
2 Inner-City Areas	30%	20%
3 Multi-Storey Buildings	-	35%
Total	**40%**	**60%**

The example shows that two potential strata are of low importance (1B and 3A) and could be left out without influencing the result of the survey.
Furthermore the distribution according to strata is important to weigh the individual stratum and to bring together the results of the strata (see page 26, Chapter 3.4.2).

3.2.3 Level of Sampling

The level of sampling is concerned with the position along the waste management process at which waste samples are taken for subsequent analysis. There are three principal levels at which sampling may take place, namely:

1. Inside the household/business such as from an internal waste bin
2. Outside the household/business such as from an external waste bin/container such as used in kerbside collection
3. A refuse collection vehicle (RCV)

Recommendation 6

The recommended level of sampling of waste is the **external waste bin/container outside the households or business properties.**

A number of criteria have been applied in determining the most appropriate level at which to recommend sample selection. Primarily the sample level must enable the fulfilment of the statistical requirements as outlined earlier in Section 2.3. It should also allow the correlation and evaluation of household level stratification criteria such as residential structure and type of collection system with waste analysis results. Lastly the sample level should not compromise the process of

manual sorting and analysis of waste such that it becomes hard to identify waste composition.
Sampling of waste at the highest level, i.e. closest to the point of waste generation, occurs inside the house or business. This level of sampling does fulfil the necessary criteria, however there are two main disadvantages. The first relates to the practical difficulties, which would be encountered in accessing internal waste bins. In addition the actual composition of the waste sample could be unusually affected due to a change in waste generation behaviour by the household/business who would need to be informed of the planned occurrence and timing of the waste analysis.

Sampling of waste at the lowest level would occur from the refuse collection vehicle. Waste within an RCV consists of mixed household waste, preventing the correlation of waste analysis results with the influencing criteria of individual households/businesses. The process of mixing and usually compaction, results in the homogenisation of waste, decreased particle sizes and makes the visual identification of waste composition more difficult and time consuming. This can also increase the costs of the sorting and analysis stage. In addition it is necessary to obtain smaller sub-samples from the whole RCV load, for sorting and analysis. This procedure, such as by "coning and quartering", increases the extent of statistical sampling errors and prevents the achievement of the required statistical standards (Section 2.3). Sampling from the level of collection vehicle does not therefore meet any of the necessary criteria as stated above.

3.2.4 Type of Sampling Unit

Sampling units are the smallest sub groups of the parent population which are separately selected, collected, sorted and analysed, and for which separate analysis results are produced.
There are three main sampling units that could be used to obtain the necessary waste samples for analysis, namely:

1. A specific waste bin **volume** such as 240 litres (l) or 1100 l; or

2. A specific **weight** of household/commercial waste such as 100 kilograms (kg); or

3. A specific **number of persons** who generate relevant waste such as 30 persons.

Recommendation 7

The recommended type of sampling unit should be based on the **volume of the waste bin**. (Please note this does not mean the volume of the waste contained within the bin.)

The use of waste bin/container volume as the sampling unit avoids disadvantages as described in "Methodology for the Analysis of Solid Waste (SWA-Tool) – **Long Version**".

There is often a variation in the volume of waste bins/containers used by a municipality with the most commonly used volumes being 120 litres (l), 240 l, 1100 l, and 2400 l. The choice of the sampling unit will usually depend on the bin type which is most commonly used in the waste analysis study area, however where there is a choice available to a municipality the following should be noted:

- The smaller the volume of the sampling unit the greater the statistical accuracy of results (relative accuracy at a given sample size of bin volume); and
- The smaller the volume of the sampling unit the greater the time required for sorting and analysis for the equivalent sample size. This may be a consideration for those undertaking the actual analysis especially where this involves an external contractor.

Recommendation 8

The sampling units have to be of similar size.

The recommended sampling unit used for a waste analysis should be the lowest common denominator of bin size from the following: 120 l; 240 l; 360 l; 660 l; 1100 l; 2400; and 3600. Bins sampled for analysis, which are less than 120 l volume, should be aggregated to one of these sample sizes.

<u>Example:</u> Bins used are 120 l and 240 l. Sampling unit should be 240 l. Where 120 l bins are sampled then two of these bins should be aggregated to form one unit (240 l)

During the demonstration stage of the project the Partner Cities used a variety of sampling units. Table 4 shows the different sampling units used, the total sample size taken, and the estimated time for analysis.

Table 4 Sampling Units Used in Demonstration Phase

Partner City	Sampling Unit	Total Sample Size per Campaign [m^3]
Brasov	1m^3 (equivalent to the respective number of bins from 120 l, 240 l, 1100 l)	45 m^3
Brescia	One 3200 litre container or one 2400 litre container	240 m^3
Krakow	1m^3 (equivalent to the respective number of bins from 120 l, 240 l, 1100 l)	45 m^3
Newcastle	One 240 litre bin (or the respective number of 120 litre bins)	57 m^3

3.2.5 Calculation of the Number of Sampling Units and Sample Size

Calculation of Overall Number of Sampling Units

The total number of sampling units required depends on 2 main criteria:

1. The variation (heterogeneity) of the waste, expressed by the natural variation coefficient. This variation coefficient is usually unknown and has to be estimated on the basis of results from past waste analyses.

2. The desired accuracy of the results.

The required total number of sampling units for a waste analysis campaign can be easily estimated by using Table 5 below. It shows the necessary number of sampling units for different natural variation coefficients and different levels of relative accuracy of results (maximum random sampling error).

Usually the natural variation coefficient of the analysed waste is not known and has to be derived from empirical values from past waste analyses.

Applying this variation coefficient to the first column of Table 5 and reading across to the required level of accuracy (refer to Recommendation 1); 10% maximum random sampling error and 95 % confidence level, the necessary number of sampling units can be looked up. These values were calculated using equation 7 (Annex 2).

Table 5 Calculation Necessary Number of Sampling Units (95 % Confidence Level)

natural variation coefficient Gauge for variation in parent population)	**necessary number of sampling units n (95 % confidence level)** with maximum allowance for random sampling error: 2.5%	5%	10%	15%	20%	30%
15%	138	35	9	4	2	1
20%	246	61	15	7	4	2
25%	384	96	24	11	6	3
30%	553	138	35	15	9	4
35%	753	188	47	21	12	5
40%	983	246	61	27	15	7
45%	1245	311	78	35	19	9
50%	1537	384	96	43	24	11
55%	1859	465	116	52	29	13
60%	2213	553	138	61	35	15
70%	3012	753	188	84	47	21
80%	3934	983	246	109	61	27
90%	4979	1245	311	138	78	35
100%	6147	1537	384	171	96	43
120%	8851	2213	553	246	138	61
140%	12047	3012	753	335	188	84
160%	15735	3934	983	437	246	109
200%	24586	6147	1537	683	384	171

Recommendation 9

If the **variation coefficient** of the analysed waste **is known** (e.g. from former waste analyses in the same area) it should be used to calculate the required number of sampling units by using Table 5.

Recommendation 10

If the **variation coefficient** of the analysed waste **is unknown** the following sample sizes for the different types of waste are recommended (regardless of the size of the chosen sampling unit):

household waste: 45 m³
mixture household/commercial waste: 80 m³
commercial waste: 100 m³

These values are based on experiences of former waste analyses and of the results of the SWA Tool project.

If the required accuracy is not reached with these values the sample size should be adjusted for the next seasonal campaign to achieve the required level of accuracy.

Table 6 Examples Calculation of Sample Size from the SWA-Tool Project

				Number of Sampling Units		Sample Size [m³]		
	Campaign no.	**Size of Sampling Unit [l]**	**VarCoeff xi (Sample)**	Necessary Number of Sampling Units n	**Applied Number of Sampling Units n**	Necessary Sample Size	**Applied Sample Size**	Difference [m³]
Brescia	3	**2400**	**42%**	68	**75**	163	**180**	17
Cracow	2	**1100**	**37%**	53	**45**	53	**45**	-8
Brasov	1	**1100**	**23%**	20	**45**	20	**45**	25
Newcastle	1	**240**	**57%**	125	**230**	30	**55**	25

Number of Sampling Units for Individual Strata

A certain amount (sample) of waste has to be analysed in order to obtain reliable results for a single stratum. The necessary number of sampling units depends on the variation of the waste (of the stratum) and the desired accuracy of the results. The frame conditions are thus identical with those for the investigation of the parent population, i.e. if the relative accuracy of +/- 10% shall be achieved as the total result of a stratum, the same number of sampling units has to be investigated as in case of parent populations.
In practical terms, strata are usually analysed as a part of a total waste analysis and as such, with smaller sample sizes. In this case the results show a lower accuracy. If the sample size for strata goes beyond a certain level, results will probably be biased and are not representative.

Recommendation 11

The **number of sampling units** of one stratum per campaign shall exceed **6** and the **sample size** shall not be less than **6 m³** (bin volume) for household waste.

For commercial waste the **number of sampling units** of one stratum shall be **15** but the **sample size** shall not be less than **15 m³** (bin volume).

These are values of experiences.

Warning: Waste analysis results which are based on a sample size of only 6 m³ are afflicted with considerable uncertainties and shall not be over-interpreted.

3.2.6 Generation of Random Sample Plan

The generation of an appropriate random sample plan according to the analysis design is necessary to ensure the validity of waste analysis results and their subsequent evaluation. The sample plan also forms the basis of the collection addresses for the relevant waste samples.

A pre-requisite for the generation of a sample plan is the availability of a selection basis for the parent population of the waste analysis e.g. the addresses of all relevant waste containers. Ideally, this should be in electronic database or spreadsheet format to enable the easy manipulation and extraction of relevant address details.

According to the analysis design it is necessary to randomly sample addresses either from the whole parent population or from the relevant sub-populations according to the designated stratification criteria (stratified random sampling).

Recommendation 12

It is recommended that the generation of a random sample plan should also include the generation of a back-up set of random sample addresses. This additional random sample plan should be used to replace those primary addresses when the collection personnel determine it is not operationally possible to identify and collect the appropriate waste sample for analysis.

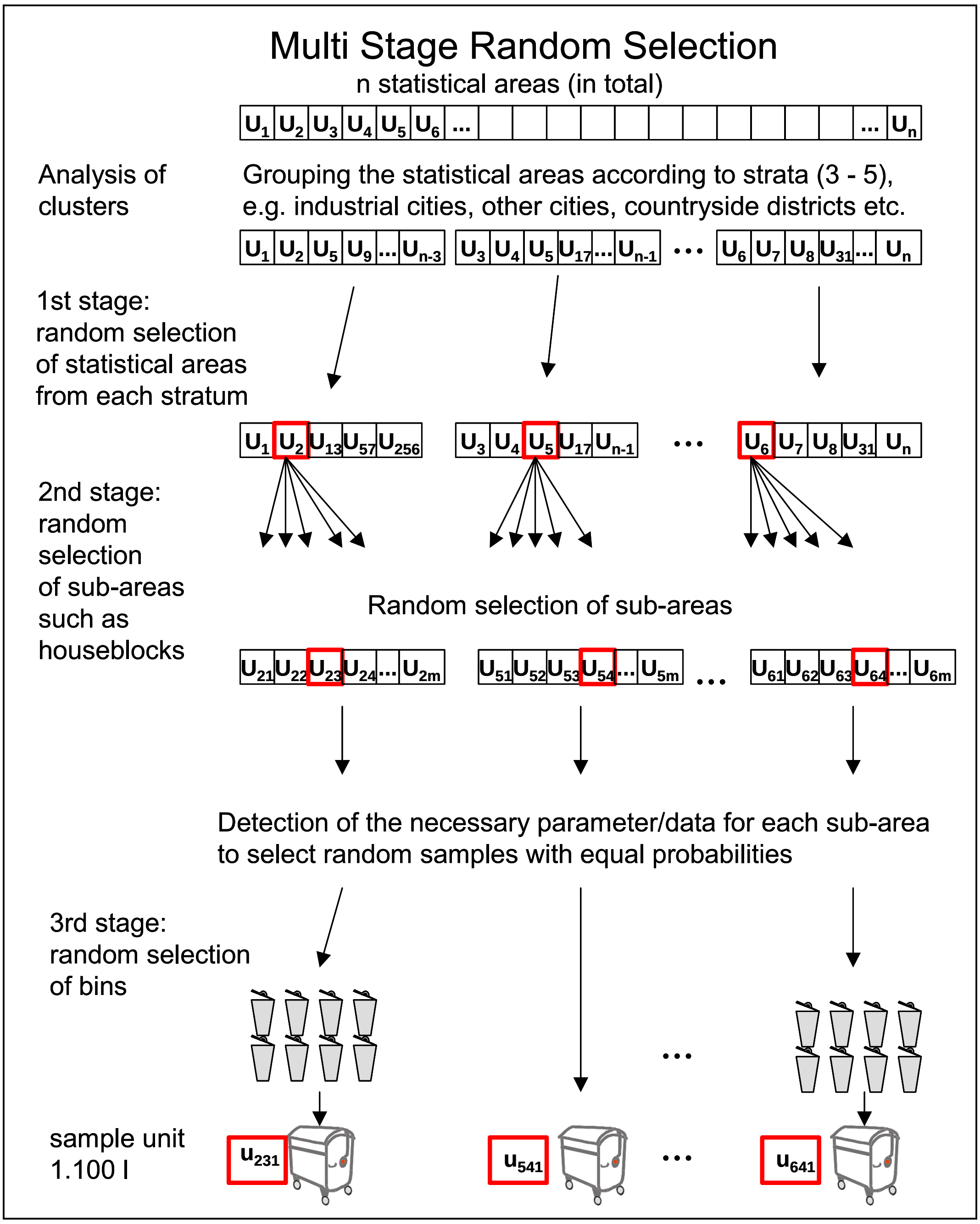
<u>Example:</u> Multistage stratified random selection

A suitable process for generating a representative waste sample is the multistage stratified random selection where several sampling operations are performed in succession. In order to achieve a multistage stratified random selection the entire survey area is initially arranged into strata. The attribution to particular strata is made on the basis of relevant background information and the pre-investigation survey for the area under study. At the level of the municipality information relating to waste management and socio-economic structure will be available to assist in the choice of relevant strata. The next stage involves the random selection of relevant sub units of statistic areas such as street blocks or enumeration districts. The final stage involves the random selection of waste bins from street blocks or enumeration districts. In order to ensure representative sampling there must be an equal probability of selection at each stage of the process. This multistage approach ensures samples are selected randomly as part of a waste analysis study. Furthermore it simplifies the sampling procedure as detailed planning and data processing are only necessary for the lower stages of the selection procedure.

Note: Where it is necessary to select waste samples from residential blocks of flats it is acceptable to use waste bin registers or records for the selection of suitable sample waste bins without compromising the required level of accuracy.

The sampling plan for the multi stage stratified random selection is illustrated in Figure 1.

Figure 1 Schematic Example of a Multistage Stratified Random Sampling Process



3.2.7 Duration of an Individual Waste Analysis Campaign

Recommendation 13

Where the normal municipal waste collection for the relevant parent population is repeated on a daily or weekly basis it is recommended that the **duration for waste sampling and sample collection covers a minimum of one weeks waste.** This will allow the sampling of waste to be spread over each working day (Monday to Friday) covering the full collection cycle and any potential variation due to non-collection of waste at a weekend.

Recommendation 14

Where the normal municipal waste collection for the relevant parent population is repeated on a bi-weekly (fortnightly) basis it is recommended that the duration for waste sampling and sample collection cover a minimum of two weeks waste i.e. the full collection cycle.

3.3 EXECUTION OF WASTE ANALYSIS

3.3.1 Collection of Samples

Recommendation 15

The collection team should **collect** the sampling units from the predetermined properties by emptying or exchanging the selected container **on the day of the regular collection** interval. Ideally this should be done without informing the property holder responsible for the production of the waste to avoid unduly influencing its composition.

NOTE: to avoid cluster effects, do not take more than one sampling unit per sampling address.

Recommendation 16

Each sample collected should be tagged with a unique identification reference code, capable of use in wet conditions. The following minimum data should be collated and recorded for each individual sample by the waste sample collection team at the time of collection

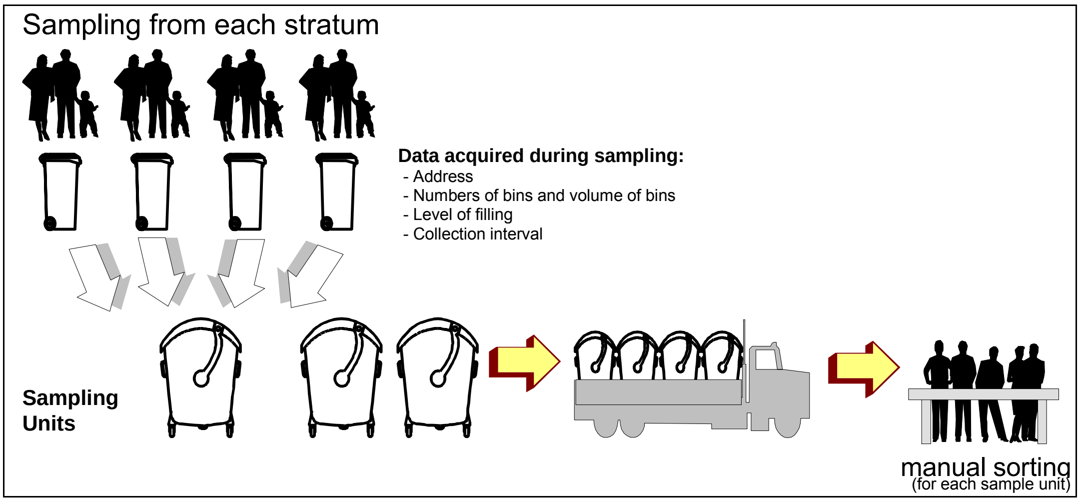
(i) Unique identification reference code
(ii) Sample address
(iii) Date of collection
(iv) Number and type of waste containers collected
(v) Visual estimation of % filling level of waste containers collected
(vi) Visual estimation of % filling level of other containers at one address to get the information for calculating the waste quantity

Further information, which may be useful for the evaluation of results if easily available concerns the **number of persons responsible for waste production** at the sample address and **the collection interval**. Where this information is not available general statistical information for a municipality concerning the average number of persons per property may be available. This information could then be useful to provide an indication of per capita waste statistics in addition to per household waste statistics.

It is important that each individual waste sample collected is not mixed with any other waste samples during collection, transportation and subsequent analysis. Once a full load of samples has been collected they should then be transported to the appropriate facilities for sorting and analysis.

An outline example of the collection process is shown in Figure 2. The sampling level is the **external waste bin/container outside the households.** In this case the sampling unit is 1 m³, here represented by 4 x 240 l bins.

Figure 2 Example of Sampling (Sampling Unit is 1 m³)



3.3.2 Sorting and Analysis of Samples

Each sampling unit is weighed and the weight is documented. Each sampling unit has to be sorted separately. The sampling unit is sorted into the categories according to a developed Sorting Catalogue (see Annex 1).

The Sorting Catalogue contains **13 compulsory primary categories** and 35 **recommended secondary waste categories**. To further assist sorting and analysis the catalogue also provides indicative examples for each secondary category for a wide range of items commonly encountered in the municipal waste stream as a guide to their appropriate classification. In addition, it is also possible to designate further tertiary or third level categories that may provide additional waste composition details according to their local waste information requirements.

Recommendation 17

1 A waste analysis record sheet (paper copy) is set up for each sampling unit.

2 The unique identification code attached to each sample is recorded against the waste analysis record to be completed.

3 The percentage-filling ratio of the waste sample container (bin) is recorded.

4 The sampling unit is weighed to an accuracy of +/- 0.1 kilograms (kg) and the weight recorded.

5 In order to reduce the sorting effort, the sampling units can be separated into two initial fractions; above 40mm and below 40mm, by screening with a 40mm mesh screen (tromel). Alternatively the waste can be sorted directly on a 40 mm screen table. This step is an aid for the sorting team but not compulsory.

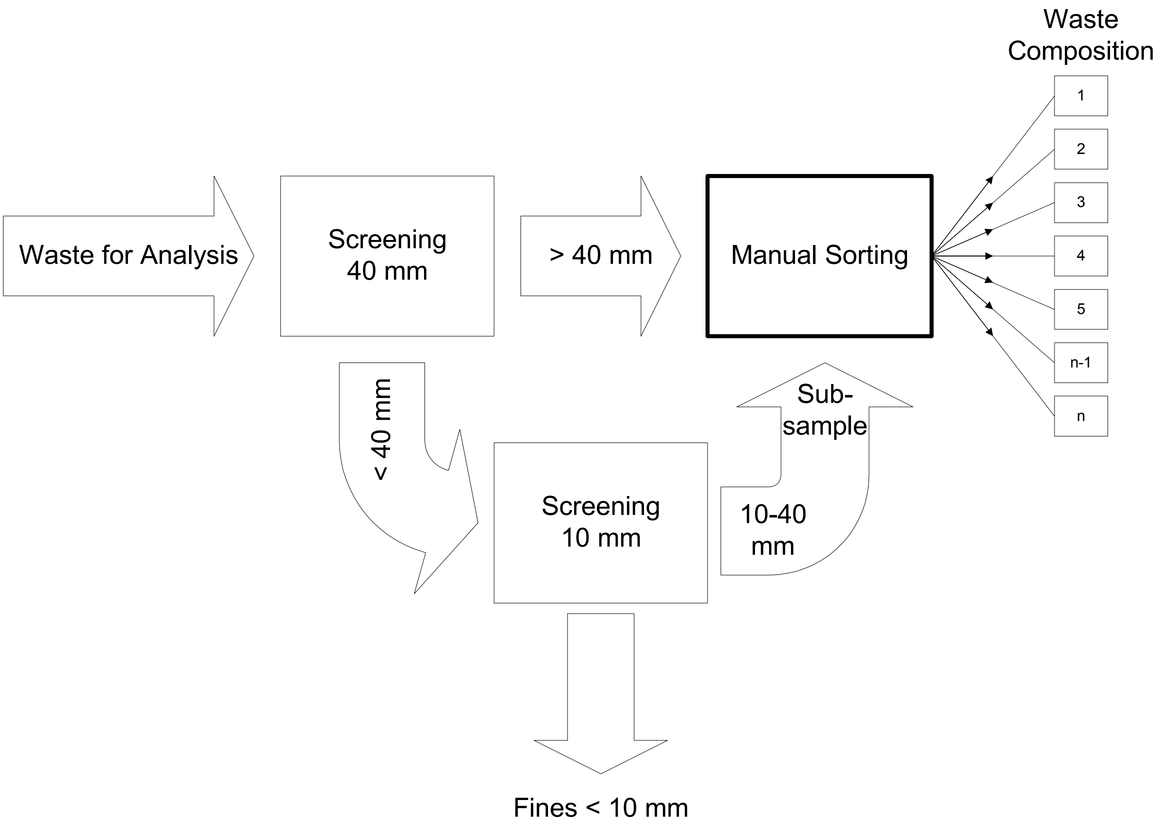
6 The above 40mm fraction is sorted into one of 12 **compulsory** primary waste categories excluding the ‘Fines’ category as specified by the SWA-Tool Sorting Catalogue (Annex 1). The weight of each category is recorded for the sampling unit to an accuracy of +/- 0.1 kg.

7 The ‘below 40mm’ fraction is further screened with a 10mm mesh screen into two fractions; ‘below 10mm’fraction and ‘a 10-40mm’ fraction.

8 The ‘below10’mm fraction is weighed to an accuracy of +/- 0.1 kg and this weight recorded as the primary category ‘Fines’ according to the SWA-Tool Sorting Catalogue (Annex 1)

9 The ‘10-40mm’ fraction is weighed, too. By coning and quartering a representative sub sample is generated and sorted according to the recommended primary waste categories specified in the Sorting Catalogue (Annex 1). The observed composition of the sub-sample is then applied to the total weight of the 10-40 mm fraction. The resulting weights are recorded and allocated to the corresponding primary waste categories.

Figure 3 Sorting Procedure



Recommendation 18

It is recommended that the determination of the optimum number of sorting team personnel according to local circumstances, should be based on a waste sorting rate of 6 man-hours per 100 kilograms of waste (refer to Annex 4).

3.3.3 Important Points of Clarification for Sorting and Classification[3]

It is important to note that the application of any of these points of clarification must **not supersede** relevant Health and Safety Regulations and Guidelines.

Table 7 Special Cases during the Sorting Procedure

Item	Description	Recommendation	Examples
Packaging Items with Contents	Packaging with contents where the content of a packaging item is suspected to weigh more than the packaging itself	The liquid content and the packaging shall be classified separately to the specific categories of the Sorting Catalogue.	filled bottles
Fraction < 10 mm in bags such as vacuum bags, house sweepings, litter for pets etc.	The contents of such bags are often easy to classify as fines and the weight of the bag forms a relatively minor part of the waste stream.	Therefore, these bags shall be classified with their content directly to the fraction < 10mm. These bags shall not be emptied, also for hygienic reasons.	vacuum bags, house sweepings, litter for pets
Composites or combined packaging where the compounds can be separated easily	The recommended classification of these items depends on whether they are of significant size or not (greater or smaller than a packet of cigarettes).	Composites or combined packaging where the compounds can be separated easily and which • have a bigger size than a packet of cigarettes: the compounds shall be classified to the specific categories. • have a smaller size than a packet of cigarettes: the compounds shall be classified to the prevailing category.	packets of cigarettes, bottles with cap, yogurt pots with alu lids
Items consisting mainly of pure categories and only small parts (< 20 % of weight) of other categories	The separation of the different materials would be possible but with substantial effort of the sorting staff.	Due to the easy classification and the small error occurring within the sorting analysis these items are classified according to the category of its main component.	handle bar (with handles of plastic), hole puncher, ring binder
Liquids in waste bins	These liquids are produced in waste bins during the degradation of the biological fraction. Usually these liquids rest on the bottom of the waste bin and shall be collected when the waste bin is emptied.	Due to the easy classification and the small error occurring within the sorting analysis these liquids shall be classified separately. They can be classified to the primary category "Organic".	

3.3.4 Health and Safety

Note: The Health and Safety Recommendations contained in this methodology DO NOT replace statutory Health and Safety rules in the respective countries for municipalities, but are intended as added guidance only (refer to Annex 3).

[3] Refer to: LANDESUMWELTAMT BRANDENBURG (1998): Richtlinie für die Durchführung von Untersuchungen zur Bestimmung der Menge und Zusammensetzung fester Siedlungsabfälle im Land Brandenburg, Teil 1, Fachbeiträge des Landesumweltamtes Nr. 34, Potsdam

3.4 EVALUATION OF WASTE ANALYSIS

3.4.1 Evaluation of Raw Data

The basis for the evaluation are the basic weight results of the sorting procedure (waste composition in kilograms) for each sampling unit.

Recommendation 19

The basic weight results shall be transferred from the record sheet (paper copy) to the Excel sheet (Annex 5). This Excel template will automatically calculate the waste composition and the required statistical data.

3.4.2 Quality Assurance

The following statistical values have to be calculated for each waste category, each campaign and for the total result:

(i) Mean
(ii) Median
(iii) Standard deviation
(iv) Variation coefficient
(v) Confidence coefficient (refers to tables of t-distribution, Annex 2)
(vi) Relative confidence interval (%)
(vii) Confidence interval (kg)
(viii) Composition (%)

Note: The statistical parameters are calculated on the basis of kg and should not be converted into percentages.

It is necessary to review the statistical results of each individual waste analysis campaign and for the overall waste analysis campaign to determine whether the desired statistical requirements of the SWA-Tool methodology (refer to Section 2.3).

In case a stratification has been applied, the results of the single strata have to be aggregated to obtain the total sample result. The total sample result has to be calculated as the weighted mean of the single stratum results.

Recommendation 20

The result of each stratum has to be weighted (example see stratification matrix, page 13) and put in the right relation. **The total result is the weighted mean of the single stratum results (see Annex 2, equation 8)**

For the calculation of errors of the total sample result of each campaign formula 10 (Annex 2) has to be used.

3.4.3 Extrapolation

The extrapolation comprises the conclusion from the obtained sample results to the parent population. Two cases may be distinguished:

Case 1:

The investigated waste type of an area (e.g. daily household and commercial waste) is permanently weighed. Thus, the total waste amount is known. The total sample result (waste composition) can be apportioned to the total waste quantity (parent population).

Case 2:

The total amount of the investigated waste type is unknown. This is the case if only household waste is subject of the waste analysis, but is not weighed separately (only the mixture of household and commercial waste is weighed). Hence, an extrapolation of the sample results to the parent population (here: household waste of an area) is necessary. The following recommendations should be considered.

The waste quantity can be extrapolated by using the following data as a reference value:

- number of sampling units, or
- number of inhabitants, or
- number of households.

Recommendation 21

The total arisings of e.g. household residual waste can be calculated by multiplication of the total sample mean by the total number of sampling units (parent population).

Recommendation 22

(i) In case of a stratification, the total arisings of e.g. household waste for a stratum should be calculated by multiplication of the stratum sample mean by the total number of sampling units within the stratum.

(ii) To obtain the total waste amount, the results of the strata have to be added (please refer to the example below). The confidence interval for a stratified sample can be calculated by using equation 10 and 11 (Annex 2).

(iii) In case of a stratification, the total arisings of e.g. household waste the total waste amount can alternatively be calculated by multiplication of the weighted mean of the individual sample means by the total number of sampling units for the area under investigation.

Example Newcastle, UK

1 Sampling unit = 240 litres
Number of strata: 2

Number of sampling units within Stratum A = 30,000
Number of sampling units within Stratum B = 60,000

Stratum A: mean household waste arisings per week = 16 kg +/- 10%

Total waste arisings per week = (16 kg x 30,000) +/- 10%

= **480 tonnes +/- 48 tonnes**

Stratum B: mean household waste arisings per week = 18 kg kg +/- 8%

Total waste arisings per week = (18 kg x 60,000) +/- 8%

= 1,080 tonnes +/- 86.4 tonnes

Addition of the results of the single strata **= 1,560 tonnes**

The total confidence interval has to be calculated using equation 10 and 11 (Annex 2).

Recommendation 23

Where a seasonal analysis involving less than four seasonal campaigns has been undertaken it may also be necessary to adjust the extrapolation of results to account for the missing seasonal investigation(s).

3.4.4 Presentation of Results

The format for the presentation of results is an important aspect of the waste analysis methodology and will affect the comparability of waste analysis results between different waste analyses. The fundamental aim of the SWA-Tool methodology is to improve the accuracy and comparability of municipal waste management statistics and the format of presentation can assist in optimising this.

Recommendation 24

It is recommended to report and present the following data:

1. Raw Data (example see Annex 5)

Raw data should be presented and reported as an MS Excel table according to the format shown in Annex 5.

2. Statistical Calculations

Statistical calculations should be presented and reported as an MS Excel table according to the format shown in Table 8. The formulas for the calculation of the statistical parameters are included in this Excel template (Annex 5).

The relative confidence interval has to be calculated and represented as result.
Very often the absolute confidence interval is shown which depends on the corresponding mean. Therefore, it is not possible to compare results of different waste analyses.

3. Evaluation of single results of strata

The evaluation of single results of each stratum should be presented and reported as a table.

4. Extrapolation of the overall results and of the waste quantification

The extrapolation of results should be reported.

5. Graphical presentation of results

The mean waste amounts of the primary waste composition categories where calculated, should also be presented graphically as MS Excel Graphs in a similar format to that in Figure 4 and Figure 5 overleaf.

Table 8 Example for the Presentation of Results

	Composition				Error Estimation			
						Confidence Interval (95%-level)		
	Sample Composition	Amount per Capita	Total Amount	Variation Coefficient (sample)	Variation Coefficient (estimator)	Dev. from the Mean in	Lower Limit	Upper Limit
Categories	% weight	kg/cap.,week	kg/week	%	%	% weight	kg/week	kg/week
Organic	34,1	5,9	3.168,2	88,0	3,8	7,4	2.932,5	3.403,8
Wood	1,0	0,2	92,5	729,2	31,4	61,6	35,5	149,5
Paper and Cardboard	22,1	3,8	2.050,4	88,0	3,8	7,4	1.898,0	2.202,8
Plastics	9,6	1,7	896,9	73,9	3,2	6,3	840,9	952,9
Glass	7,0	1,2	654,7	136,1	5,9	11,5	579,4	730,0
Textiles	3,1	0,5	289,8	262,6	11,3	22,2	225,5	354,1
Metals	5,0	0,9	461,4	107,6	4,6	9,1	419,5	503,4
Hazardous Waste	0,5	0,1	43,9	508,1	21,9	42,9	25,1	62,8
Complex Products	5,0	0,9	464,2	419,7	18,1	35,5	299,5	628,8
Inert	7,6	1,3	701,9	472,3	20,4	39,9	421,8	982,1
Other Categories	4,1	0,7	384,3	245,7	10,6	20,8	304,5	464,1
Fines < 10 mm	1,0	0,2	91,6	419,1	18,1	35,4	59,1	124,0
Total	**100,0**	**17,4**	**9.300,2**	**63,7**	**2,8**	**5,4**	**8.799,8**	**9.800,7**

Figure 4 Example for the Graphical Presentation of Results

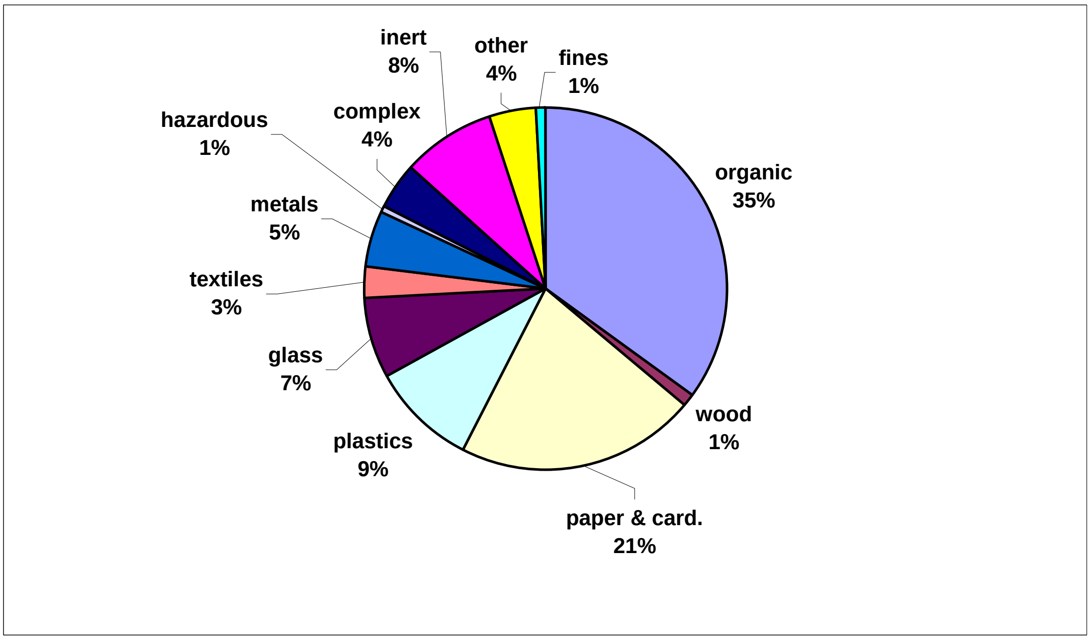
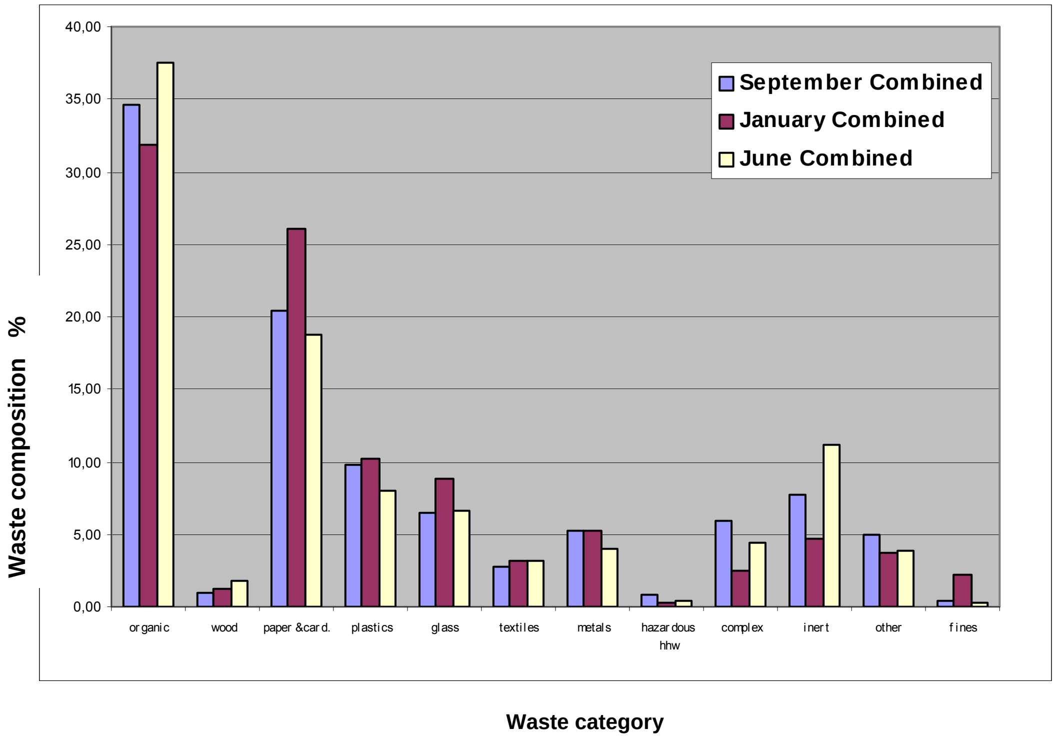


Figure 5 Example Comparison of Seasonal Primary Waste Composition



ANNEX I SORTING CATALOGUE

Primary Categories	Code	Secondary Categories	Code	Notes	Typical Examples
Organic	OR1	Biodegradable Kitchen/Canteen Waste	OR1 01	All biodegradable waste originating in domestic kitchen or commercial/industrial canteen	Bread; Coffee grinds; Cooked or Uncooked food items; Food leftovers; Fruit and vegetables; Meat and fish; Pet foods; Tea bags
		Biodegradable Garden/Park Waste	OR1 02	All biodegradable waste originating in a domestic garden or municipal park, garden, or landscaping feature	Flowers; Fruit and vegetable garden waste; Grass Cuttings; Hedge trimmings; Leaves; Pruning; Tree branches; Weeds
		Other Biodegradable Waste	OR1 03	All biodegradable waste not applicable to either of the above categories	Animal remains; Bones Faeces
Wood	W2	Untreated Wood	W2 01	All wood/cork items without paint, varnish, preservative, sealant etc	Bottle corks, Cork packaging, Untreated Pallets Solid timber and timber fragments untreated
		Treated Wood	W2 02	All wood/cork items with paint, varnish, preservative, sealant etc	Particle board (e.g. chipboard, plywood, mdf) Solid timber and timber fragments, treated Wood fencing- treated; Wood from DIY - treated Wood furniture – treated; Wood kitchen units- treated Wood work tops- treated
Paper and Cardboard	PC3	High gloss paper/card and wallpapers	PC3 01	Non-biodegradable paper	Glossy brochures e.g. travel brochures; shop catalogues Glossy magazines e.g. Cosmopolitan, Elle High gloss papers e.g. photographic papers Waste wallpapers
		Paper/card – packaging	PC3 02	All non-glossy paper card packaging	Cereal packets; Cleaning product cartons; Corrugated packaging cardboard (bulk and individual); Fast Food Paper bags/wrapping; Noodle and egg boxes; Other food/pet food/ non-food container packaging; Paper bags; Tissue boxes; Toy boxes; Washing powder boxes; Waxed card liquid cartons; Wrapping paper
		Newspapers	PC3 03	Loose and stapled newsprint	Local and national newspapers (paid and free) Newsprint-type advertising publications; Other newsprint
		Other Paper/card– non packaging	PC3 04	All paper card otherwise not mentioned	Birthday type cards; Books; Computer printouts; Diaries; Envelopes; Files and folders; Invoices; Kitchen roll; Letters; Loose leaf paper; Non glossy brochures and catalogues; Non-glossy junk mail; Office paper; Photocopies; Posters; Telephone directories; Tickets; Tissue paper; Toilet papers; Writing paper; Yellow pages

Primary Categories	Code	Secondary Categories	Code	Notes	Typical Examples
Plastics	PL4	Plastic Film –packaging	PL4 01	All packaging bags and refuse sacks	Biscuit wrappers; Cereal packets (inside box); Cling film; Compost/peat bags; Crisp packets; Frozen food bags; Packaging plastic film; Plastic food bags/pet food/non food bags; Sandwich bags
		Plastic Film – non packaging	PL4 02	All non packaging bags and refuse sacks	Cellotape; Garden sheets; Non-packaging film; Plastic bags; Refuse sacks; Shopping bags; Tarpaulins
		Dense Plastic Bottles/Jars (P)	PL4 03	All clear and coloured plastic bottles and jars	All plastic bottles/jars e.g.; Alcoholic drinks; Bleaches; Detergents; Household/pet/garden products; Laundry liquid; Milk; Oil; Soft drinks; Vinegar; Water
		Dense Plastic – other packaging	PL4 04	All other clear and coloured plastic packaging except bottles and jars	Appliance packaging; Cleaning tubes; Cosmetic tubes; Egg boxes; Food cartons; Food packing trays; Food tubes; Ice cream cartons; Margarine tubs; Plastic lids; Ready meal trays; Roll on deodorant bottles; Trays; Yoghurt cartons; Bottle tops
		Dense Plastic –non packaging	PL4 05	All non-packaging dense plastic items	Air freshener holders; Bank/credit cards; Buttons; CDs'; music cassettes; Cosmetic/glue/paint applicators; Disposable razor blades; Floor Linoleum (Lino); Floor Tiles (vinyl/plastic); Garden hoses; Gardening equipment; Hard plastic; Household/car/garden accessories; Lighters; LPs; Pens; Plant pots; Plastic curtain rails; Plastic frames; Plastic sunglasses; Plastic toys; Rulers; Rulers; Seed trays; Shoes (Plastic only); Toilet lids; Toothpastes; Tubes/pumps; Video cassettes; Washing up bowls/racks
Glass	G5	Glass Container Packaging Clear	G5 01	All clear glass bottles and jars	Alcoholic and non-alcoholic drinks bottles/jars (e. g. beer, cider, milk, water, wine) Food jars (e.g. baby foods, coffee, jams, pickles, sauces) Medicine bottles
		Glass Container Packaging Brown	G5 02	All brown glass bottles and jars	Alcoholic and non-alcoholic drinks bottles/jars (e.g. beer, cider, milk, water, wine) Food jars (e.g. baby foods, coffee, jams, pickles, sauces) Medicine bottles
		Glass Container Packaging Other	G5 03	All coloured glass bottles and jars except brown and clear glass	Alcoholic and non-alcoholic drinks bottles/jars (e.g. beer, cider, milk, water, wine) Food jars (e.g. baby foods, coffee, jams, pickles, sauces) Medicine bottles
		Miscellaneous Non Packaging Glass	G5 04	All non-packaging glass	Cookware (e.g. pyrex, drinking glasses) Flat glass (e.g. table top, window, mirrors, reinforced, windscreens) Light bulbs (e.g. normal, fluorescent, energy saving Mixed broken glass Television/ computer screens separated only

Primary Categories	Code	Secondary Categories	Code	Notes	Typical Examples
Textiles	T6	Clothes	T6 01	Natural and man-made clothing items excluding shoes	Trousers; Skirts; Socks; Stockings; Tights; Underwear; Shirts; Blouses; Jumpers; Cardigans; Coats; Hats; Gloves
		Non-clothing textiles	T6 02	Natural and man-made textiles and furnishings except clothes and shoes	Balls of wool; Blankets; Braids; Carpets; Cloths; Cords; Curtains; Household soft furnishings and upholstery; Mats; Pillow cases; Pillows; Rags; Ropes; Rugs; Sheets; Threads; Towels
Metals	M7	Ferrous Packaging	M7 01	Ferrous food, beverage and non-food cans and containers	Biscuit containers; Packaging for carbonated drinks, Fish, Pet food etc.; Shoe polish cans; Soft drinks; Soups; Sweets; Tinned food; Aerosols (deodorant, perfume, hairspray)
		Non-ferrous Packaging	M7 02	All non-ferrous Cans and Containers and Aluminium Foils etc.	Aluminium foil sheets; Biscuits containers; Cake and pie containers; Carbonated drinks; Containers; Fish; Pet food; Shoe polish cans; Soft drinks; Soups; Sweets; Take away; Tinned food; Other food/non-food/ pet food containers; Aerosols (deodorant, perfume, hairspray)
		Miscellaneous Ferrous	M7 03	All ferrous items except food, beverage and non-food cans and containers	Bike parts; Building materials/DIY materials; Car parts; Cutlery; Keys; Licks; Metal shelves; Nails; Paper clips; Plumbing; Pots and pans; Radiators; Ring pulls; Safety pins; Screws; Tools
		Miscellaneous Non-ferrous	M7 04	All non-ferrous items except Aluminium Cans and Containers and Aluminium Foils	Keys; Cutlery; Locks; Ring pulls; Tools; Car parts; Radiators; Metal shelves; Pots and pans; Screws; Nails; Building materials/DIY materials; Plumbing; Bike parts
Hazardous Household Waste	H8	Batteries/Accumulators	H8 01	All types of household and car batteries including rechargeable and non-rechargeable	Lead acid Nickel cadmium Other car and household batteries and accumulators (including rechargeable batteries
		Miscellaneous hazardous waste	H8 02	All other potentially hazardous household type waste	Asbestos; Cooking oils; Fire extinguishers; Garden/household chemicals; Glues and solvents; Medicines; Methylated spirits; Mineral, synthetic and non-edible organic oils and fats and their filters; Motoring products; Paint products; Photo chemicals; Refrigerants; White spirits
Complex Products	C9	Composite/Complex Packaging	C9 01	Any complex/composite packaging that cannot be easily separated into its component materials and is therefore difficult to classify conventionally	Aluminium Foil-coated card, liquid containers e.g. milk; fruit juice
		Composite/Complex Non-packaging	C9 02	Any complex/composite item which is not packaging that cannot be easily separated into its component materials and is therefore difficult to classify conventionally	Appliance parts Car parts Engine parts Sandals (multi-material only) Shoes (multi-material only)

Primary Categories	Code	Secondary Categories	Code	Notes	Typical Examples
Complex Products	C9	Mixed WEEE	C9 03	Large Household Appliances Small Household Appliances IT and Telecommunications Equipment: Lighting Equipment: Toys: Monitoring and control instruments:	Air conditioners; Answering machines; Car racing sets; Carpet sweepers; Clocks; Clothes dryers; Coffee makers; Compact fluorescent lamps; Computers; Cookers; Copiers; Dishwashers; Drills; Electric knives; Electric stoves/hotplates; Electric toothbrushes; Electric trains; Electrical and Electronic Tools; Fax; Freezers; Fryers; Hair dryers; Hand held video game consoles; Heating appliances; Heating regulators/thermostats; High intensity discharge lamps; Irons; Laptops; Large cooling appliance; Low pressure sodium lamps; Microwaves; PCs; Printers; Refrigerators; Saws; Scales; Sewing machines; Shavers; Smoke detector; Straight fluorescent lamps; Telephones/Mobile phones; Telex; Toasters; Vacuum cleaners; Video games; Washing machines
Inert	IN10	Soil and Stones	IN10 01		Boulders; Bricks; Gravel; Pebbles; Sand; Soil; Stones
		Miscellaneous inert	IN10 02	Any 'Inerts' except soil and stones	Ceramics Clay plant pots Crockery Stone/ceramic floor and wall tiles Vases
Other Categories	U11	Nappies	U11 01		Children's disposable nappies
		Health Care/Biological Wastes	U11 02	Household Medical Waste	Dressings Swabs Syringes
		Miscellaneous Categories	U11 03	Any other material that is difficult to classify under any other categories	
Fines	F12	10mm sieved fraction	F12 01		Ashes Sand Small fragments <10mm of all above categories

ANNEX II STATISTICAL BACKGROUND

PART A THEORY STATISTICS

Definitions[4]

Confidence Interval:
An interval computed from sample values. Intervals so constructed will straddle the estimated parameter 100(1-α) of the time in repeated sampling. The quantity (1-α) is called the *confidence level*.

Confidence Level:
A probability associated with an confidence interval that express the probability that the interval will include the parameter under study.

Proportional Allocation:
An allocation procedure that partitions the sample size of the strata when using stratified random sampling.

Standard Deviation:
The standard deviation of a set of measurements $x_1,x_2,.......,x_n$ is equal to the positive square root of the variance of the measurements.

Stratified Random Sample:
A sample obtained by separating the population elements into non overlapping groups, called strata, and then selecting a simple random sample within each stratum

Variance:
The variance of set of n measurements $x_1,x_2,.......,x_n$ is the average of the squares of the deviations of the measurements about their mean.

Standard Error:
The precision of an estimator is measured by its standard deviation; hence the standard deviation of an estimator is called standard error.

Population:
A finite or infinite collection of measurements or individuals that comprises the totality of all possible measurements within the context of a particular statistical study. It is the set representing all observations of interest to the sample collector.

Parent Population:
Here: Whole quantity of waste (e.g. daily household and commercial waste) in the survey area

Sample:
Any subset of a population. Subset of measurements selected from the population of interest.

[4] Mendenhall, Reinmuth, Beaver; Statistics for Management and Economics, 7th edition
Business Research Methods, Zigmund, Oklahoma State University, 5th edition

Coefficient of Variation:
A relative measure of variability in which the standard deviation is expressed as a percentage of the mean.

Sampling Design:
The sampling design or survey design specifies the method of collecting the sample

Element: An element is an object on which measurement is taken

Sampling Units:
Sampling units are non-overlapping collections of elements from the population. In some cases a sampling unit is an individual element.

Description of the sample

The following parameters are appropriate measures for the description of a sample:

The **number of sampling units**: **n**

The **mean** of the measured values is

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Variance of the sample: The variance of set of n measurements $x_1,x_2,...,x_n$ is the average of the squares of the deviations of the measurements about their mean.

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2 \qquad \text{(equation 1)}$$

Standard deviation of the sample: The standard deviation of a set of measurements x_1, x_2, x_3,..., x_n is equal to the positive square root of the variance of the measurements. The standard deviation is calculated by equation 2:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2} \qquad \text{(equation 2)}$$

Coefficient of variation of sample: is a relative measure of variability in which the standard deviation is expressed as a percentage of the mean.

$$\text{var}\,coeff\,(x_i) = \frac{s}{\overline{x}} \qquad \text{(equation 3)}$$

Inference and Measure of its Accuracy

The use of statistical procedures in the waste analysis situation has two objectives:

(1) the **inference** and

(2) a measure of its **accuracy**.

Inference

The objective of **inferential statistics is to make predictions** about specific parameters (mean, variance, coefficient of variance) of a parent population based on information contained in a sample from this population.

Measure of accuracy

A statistical problem would be incomplete without reference to a measure of the accuracy of inferential procedures.

In waste management usually **interval estimators** are employed to estimate a population parameter (please see example Table 10). When an interval estimator is employed the pair of numbers obtained from the estimator is **called an interval estimate** or **confidence interval** (bandwidth) for the parameter. The large number, which locates the upper end of the interval is called the upper confidence limit. Similarly, the number that locates the lower extreme of the interval is called the lower confidence limit.

The probability that a confidence interval will enclose the estimated parameter is called the **confidence level.**

The confidence level measures the proportion of samples that produce a confidence interval containing the population parameter. A good confidence interval is one that is as narrow as possible and has a confidence level near 1. The narrower the interval, the more exactly the estimated parameter is located. The larger the confidence level, the more confidence we have that a particular interval encloses the estimated parameter.

The confidence level gives a measure of the confidence one can place in the confidence limits constructed from the data contained in a sample. In that sense the width of an interval and its associated confidence level measure the accuracy of the confidence interval.

Larger samples provide more information to use in forming the interval estimate. Therefore, for a given confidence level the larger the sample the narrower will be the resulting confidence interval.

In the following the steps for the **calculation of a so called relative confidence interval** are described.
Coefficient of variation of the estimator: The coefficient of variation is to be divided by the square root of n. One obtains a relative measure of variation that describes the deviation of the sample proportion from the true proportion (in the parent population).

$$\operatorname{var} coeff\ (\hat{\bar{X}}) = \frac{s}{\bar{x}\sqrt{n}} \qquad \text{(equation 4)}$$

Maximum allowance for random sampling error:

The **maximum allowance for random sampling error** is a suitable measure to describe the uncertainty of estimation procedures, as calculated according to equation 5. The maximum allowance for random sampling error describes the bandwidth of a confidence interval at a certain confidence level (e.g. 1-α = 95%)

$$\varepsilon_{\hat{\Theta},r} = \frac{t_{\alpha;n-1} \cdot \operatorname{var} coeff\,(x_i)}{\sqrt{n}} \cdot \sqrt{\frac{N-n}{N-1}} \qquad \text{(equation 5)}$$

$t_{\alpha;n-1}$: Confidence coefficient (from tabulated- t-distribution with error probability α and n-1 degrees of freedom)

varcoeff(x_i): Variation coefficient of single values from the sample

$\hat{\Theta}$: estimate value for the wanted parameter in the parent population

n: Number of sampling units

N: number of survey units in the parent population

$\sqrt{\frac{N-n}{N-1}}$: Correction of finiteness, giving evidence that at n $\rightarrow$ N the sample error strives towards zero. For small samples from large parent populations the factor is $\approx$ 1

The maximum allowance for random sampling error $\varepsilon_{\hat{\Theta},r}$ is, as the estimation parameter, a random variable and approximately normally distributed for sample sizes larger but 30 sampling units. I.e. the expressed accuracy of the maximum allowance for random sampling error is afflicted with a certain probability of admittance, resp. error probability. This uncertainty is expressed by the factor $t_{\alpha;n-1}$ (confidence coefficient) in the equation 5. Usually it is aspired to reach error probabilities of $\alpha \leq 5$ percent.

Calculation of a confidence interval:

The variance of the parent population σ^2 is usually unknown in the course of sample surveys. The variance of the parent population can approximately be estimated by the variance of the sample: $\sigma^2 \approx s^2$.
In this case the t-distribution as well as the corresponding confidence coefficients ($t_{\alpha;n-1}$) have to be applied.

The following is a step-by-step procedure for calculating confidence intervals:

1. Calculate $\bar{x}$ from the sample
2. Assuming σ is unknown, the population standard deviation must be estimated by finding s (sample standard deviation)

3. Estimate the coefficient of variation of the mean, utilising the following formula

$$\operatorname{var} coeff\ (\hat{\bar{X}}) = \frac{s}{\bar{x}\sqrt{n}}$$

4. Determine the confidence coefficient (z-value) $t_{\alpha;n-1}$ from table of t-distribution associated with the confidence level desired. Please use the z-values for two tailed questions. The table below gives an example for α = 5 % and a two tailed question (shaded cells).

Table 9 Distribution of $t_{\alpha;n-1}$ for Given Probability Levels

	Error probability (α), One-Tailed Questions				
	0.10	**0.05**	**0.025**	**0.01**	**0.005**
	Error probability (α), Two-Tailed Questions				
df	**0.05**	**0.10**	**0.05**	**0.02**	**0.01**
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
30	1.310	1.697	2.042	2.457	2.750
35	1.306	1.690	2.030	2.438	2.724
40	1.303	1.684	2.021	2.423	2.704
45	1.301	1.679	2.014	2.412	2.690
50	1.299	1.676	2.009	2.403	2.678
60	1.298	1.671	2.000	2.390	2.660
120	1.289	1.658	1.980	2.358	2.617
∞	1.282	1.645	1.960	2.326	2.576

5. Calculate the confidence interval *C.I.*, utilising the following formula:

$$C.I. = \bar{x} \pm \frac{t_{\alpha;n-1} \cdot \operatorname{var} coeff\,(x_i)}{\sqrt{n}} = \bar{x} \pm t_{\alpha;n-1} \cdot \operatorname{var} coeff\,(\hat{\bar{X}}) \qquad \text{(equation 6)}$$

PART B EXAMPLE FOR CALCULATION OF A CONFIDENCE INTERVAL

The following example shows how calculating a confidence interval can be utilised in waste analyses.
The data in the table below represent the paper/cardboard content of 24 sampling units (results of a commercial waste analysis). Each sampling unit had the volume of 1 m³.

Table 10 Content of Paper/Cardboard in Sampling Units

Number	Weight [kg]
1	53.15
2	14.45
3	19.75
4	26.70
5	29.95
6	18.75
7	9.00
8	7.20
9	26.57
10	33.45
11	15.65
12	26.77
13	19.03
14	21.95
15	33.25
16	24.37
17	3.55
18	8.95
19	43.00
20	32.71
21	11.06
22	19.58
23	16.30
24	16.00

Description of the Sample

Number of sampling units: n = 24

The **mean** of the measured values is

$\bar{x}$ = 22.13 kg

The **variance** of the measured values is

s^2 = 130.52 kg²

The **standard deviation** for the measured values is

s = 11.42 kg

The **coefficient of variation** for the measured values is

var *coeff* (x_i)= 51.62 %

Inference and measure of its accuracy

Calculation of the confidence interval

The following step-by-step procedure can be used for the calculation of the confidence interval, using the given data:

1. Calculate $\bar{x}$ (mean) from the sample. $\bar{x}$ = 22.13 kg

2. As σ is unknown, the population standard deviation must be estimated by s (**sample standard deviation**) s = 11.42 kg

3. Estimate the **coefficient of variation of the mean**, utilising the following formula

$$\operatorname{var} coeff\,(\hat{\bar{X}}) = \frac{\operatorname{var} coeff\,(x_i)}{\sqrt{n}}$$ = 10.54 %

4. Determine the **z-values** ($t_{\alpha;n-1}$ from table of t-distribution, see Table 9) associated with the confidence level desired (here: 1-α = 95%). $t_{\alpha;n-1}$ = 2.07 (for: α = 0.05, two-tailed, resp. 1-α = 0.95; n-1 = 23)

5. Calculate the confidence interval, utilising the following formula:

$$C.I. = \bar{x} \pm \frac{t_{\alpha;n-1} \cdot \operatorname{var} coeff\,(x_i)}{\sqrt{n}} = \bar{x} \pm \left(t_{\alpha;n-1} \cdot \operatorname{var} coeff\,(\hat{\bar{X}})\right)$$

$$C.I. = 22.13kg \pm (2.07 \cdot 10.54\%) = 22.13kg \pm 21.8\% = 22.13kg \pm 4.82\,kg$$

So it is expected that the population mean, μ, is contained in the range from 17.31 kg and 26.95 kg. Intervals constructed in this manner will contain the true value of μ 95 percent of the time.

Conclusions and recommendations

It is **recommended** that as a measure of statistical accuracy of results a **relative** confidence interval shall be employed with a **confidence level of 95%** and the **relative interval** for the predominant categories organic, paper, glass, plastic, metal and fines of **20%.**

This is a necessary parameter to calculate the number of sampling units for the waste analysis.

PART C DETERMINATION OF NUMBER OF SAMPLING UNITS AND SAMPLE SIZE

The necessary number of sampling units depends on:

- the demand on the aspired accuracy of the results (expressed by the maximum allowance for random sampling error $\varepsilon_{\hat{\Theta},r}$)

- the demand on the confidence level (expressed by the confidence coefficient (z-value) of the t-distribution $t_{\alpha;n-1}$)
- variance of the population (expressed by the coefficient of variation var *coeff* (x_i))
- sample proportion $f = \frac{n}{N}$

The necessary number of sampling units can be determined by equation (7)

$$n = \left(\frac{t_{\alpha;n-1} \cdot \text{var}\, coeff\,(x_i)}{\varepsilon_{\hat{\Theta},r}} \right)^2 \qquad \text{for } f = \frac{n}{N} < 0.05 \qquad \text{(equation 7)}$$

While the demand on accuracy and the confidence level are values that can be stipulated according to the aspired accuracy of the survey, the variance of the parent population constitutes a kind of “natural constant” which must be determined by preliminary surveys or can be taken from comparable surveys in the past.

Table 11 shows the calculated (equation 7) necessary number of sampling units for different natural variation coefficients and different levels of relative accuracy of results (maximum random sampling error); the confidence level is 95 %.

Table 11 Calculation Necessary Number of Sampling Units (95 % Confidence Level)

natural variation coefficient Gauge for variation in parent population)	**necessary number of sampling units n (95 % confidence level)** with maximum allowance for random sampling error					
	2.5%	5%	10%	15%	20%	30%
15%	138	35	9	4	2	1
20%	246	61	15	7	4	2
25%	384	96	24	11	6	3
30%	553	138	35	15	9	4
35%	753	188	47	21	12	5
40%	983	246	61	27	15	7
45%	1245	311	78	35	19	9
50%	1537	384	96	43	24	11
55%	1859	465	116	52	29	13
60%	2213	553	138	61	35	15
70%	3012	753	188	84	47	21
80%	3934	983	246	109	61	27
90%	4979	1245	311	138	78	35
100%	6147	1537	384	171	96	43
120%	8851	2213	553	246	138	61
140%	12047	3012	753	335	188	84
160%	15735	3934	983	437	246	109
200%	24586	6147	1537	683	384	171

If the sampling ratio *f* is small, i.e. the number of elements in the parent population is large in proportion to the number of sampling units, the necessary number of sampling units is particularly dependent on so-called natural variation coefficients.

Example:

The natural variation coefficient for household waste is about 30%. The aspired accuracy of the result (expressed by the maximum allowance for random sampling error $\varepsilon_{\hat{\Theta},r}$) is ± 10%. Then for a confidence interval at a 95% level the necessary number of sampling units *n* can be calculated as follows.

$$n = \left(\frac{1.96 \cdot 0.3}{0.1}\right)^2 \approx 35$$ (see Table 11)

Similarly the necessary number of sampling units for a certain waste component for example 20% accuracy for plastics can be calculated (if the variation coefficient for plastic is known or can be estimated).

PART D STRATIFIED RANDOM SAMPLING PROCEDURE

If a stratified random sampling procedure has been used the results for each stratum have to be disclosed separately. For the calculation of the overall result the results of the single strata have to be weighed and put in the right relation, according to its portion in the parent population. **The total result is the weighed mean of the single stratum results.**

$$\hat{\bar{X}} = \bar{x} = \frac{1}{N}\sum_{h=1}^{L} x_h \frac{N_h}{N} = \frac{1}{N}\sum_{h=1}^{L} \bar{x}_h N_h = \sum_{h=1}^{L} \bar{x}_h \left(\frac{N_h}{N}\right)$$ (equation 8)

h = 1,2,…,L (number of strata)

The standard deviation *s* for the estimator $\hat{\bar{X}}$ of the total average can be calculated according to the following formula

$$s_{\hat{\bar{X}}} = \sqrt{\sum_{h=1}^{L}\left(\frac{N_h}{N}\right)^2 \frac{s_h^2}{n_h}\left(1 - \frac{n_h}{N_h}\right)}$$ (equation 9)

or

$$s_{\hat{\bar{X}}} = \sqrt{\sum_{h=1}^{L}\left(\frac{N_h}{N}\right)^2 \frac{s_h^2}{n_h}} \quad \left(for \frac{n_h}{N_h} \langle 0{,}05\right)$$ (equation 10)

where N_h is the number of elements in stratum h and $N = \sum_{h=1}^{L} N_h$ is the size of the overall population.

The confidence interval *C.I.* can be calculated according to

C.I. = $\bar{x} \pm 1.96\, s_{\hat{\bar{X}}}$ (equation 11)

ANNEX III HEALTH AND SAFETY[5]

The following health and safety guidelines are intended as an indicative guide based on research of previous waste analyses and the experiences of the Partner Cities during the Demonstration phase of the SWA Tool Methodology. *NOTE*: These guidelines DO NOT substitute statutory health and safety rules and regulations in the respective country of a municipality undertaking a waste analysis.

Potential hazards which generally occur during the sampling, sorting and analysis stages of a waste analysis include :

- Cuts and punctures from handling hazardous materials (needles, broken glass, razor blades, aerosol cans, chemicals, etc.)
- Slipping and falling
- Heats stress and fatigue
- Traffic or heavy equipment movement
- Noise exposure
- Household hazardous wastes
- Medical wastes and sharps
- Bloody objects
- Hypodermic needles

Minimum Safety Equipment and Clothing for the sampling and sorting personnel should include:

- Hi-visibility jackets
- First aid kit
- Fire extinguisher
- Overalls (splash proof and sharp proof)
- Sharp proof gloves
- Steel toe capped boots
- Face mask
- Full face goggles/eye protection
- Safety helmet
- Anti bacterial hand/face wash
- Enzyme based deodorisers
- Ear defenders
- Site specific safety plan
- Portable telephone
- Eye wash kit
- Moist, disposable towelettes

[5] This chapter is based on the experience of the S.W.A.-Project Team and on the following waste analysis guidelines: CIWMB (CALIFORNIA INTEGRATED WASTE MANAGEMENT BOARD) (1999): *Statewide Waste Characterization Study: Results and Final Report*, (appendix C.2 guidelines Governing Health and Safety Measures C-21-C32)
Wales protocol
SÄCHSISCHES LANDESAMT FÜR UMWELT UND GEOLOGIE (1998): *Richtlinie zur einheitlichen Abfallanalytik in Sachsen*, Materialien zur Abfallwirtschaft, (chapter 4.1 pp. 7-8)

Supervisory Personnel Responsibilities

Supervisory personnel are responsible for the following:

1. Familiarity with and provision of relevant local emergency services telephone numbers.

2. Ensure all site personnel have received, and documented **training** on the following health and safety issues as a minimum:

- Handling (lifting, transporting, opening where necessary) different kinds of containers (plastic sacks, wheeled bins 120/ 240 l, container from 1100 to 3300 l)

- Eating, smoking or drinking during the sorting activities is strongly prohibited. Plenty of fluids (e.g. water, sport drinks etc..) and single use, disposable cups must be available at any times in a separated area. Hands and faces must be washed before eating and drinking.

- The sorting personnel must wear sharp proof gloves, full face goggles or safety glasses with splash shields, a face mask, disposable splash proof and sharp proof overalls and use safety boots.

- The sorting staff must be able to identify hazardous wastes. If any hazardous wastes are detected, the supervisor shall be notified.

- Use of relevant electrical equipment in the working area

- Instructions for obtaining first aid

- Dealing with any serious accident or other emergency situation, such as a fire in the working area

- At the end of each shift, removing all disposable clothing into a plastic trash bag, and place the bag into a container. All sorters shall shower at the end of each shift.

- The sorted waste shall be stored separately in closed containers or be deposited daily. The ground of the sorting area shall be cleaned mechanically at least once per day.

3. In addition the supervisors must ensure the following:

  - Protective equipment is properly maintained and inspected and properly used by all.

  - collection and sorting staff have read understood and signed the health and safety policy containing the issues mentioned under this chapter of the guideline.

  - safety guidelines are followed by the sorting and collection personnel.

Medical Aspects

All waste sorting personnel shall be in good physical condition and shall not be sensitive to odours and dust.

It is recommended that the contractor of a waste analysis shall ensure that all staff, including support staff, who will be working on any of the collection or sorting activities described in this chapter have received the following injections: **Tetanus, Polio, Hepatitis A, Hepatitis B**

ANNEX IV COST OF WASTE ANALYSES

The selection and determination of the most appropriate analysis design partly depends on the potential **costs**. Research conducted as part of this project has revealed that there is little published information regarding the costs of various waste analysis designs. The actual costs of a waste analysis for a particular municipality are subject to a number of varying factors such as costs and availability of personnel and equipment, the need for training, health and safety costs, and the waste analysis design itself particularly the overall sample size and number of sampling units. Therefore this section provides indicative guidelines only, regarding typical cost-issues that require consideration prior to undertaking a waste analysis program.

Research of past waste analyses and the experience of the Partner Cities during the demonstration phase of this project have highlighted the following relevant cost issues:

1. **Costs of waste analyses** investigated for this report vary widely which may be due to differing

   - Information needs
   - Levels of sample acquisition
   - Waste streams investigated or
   - Levels of statistical accuracy.

   Waste analyses can generally be divided into four stages to describe their costs:

   - Planning the Analysis
   - Selecting Samples
   - Sorting procedure
   - Interpretation of Results

2. The **costs of planning the analysis** and the **interpretation of results** are mainly driven by the information needs of the client. The more information required the higher the costs.

> The data provided by the partners about man-hours for **planning the analsyis** varied within a range between **40 and 200 man-hours**.

3. The **costs of sampling** depend on the number of samples that are selected and the distance between the sampling locations. The **costs of sorting** depends on the amount of waste which has to be sorted which correlates with the number of samples.

> Experience shows that it takes approximately **6 man-hours to sort 100 kg waste manually.**

4. The **number of samples** depends on the statistical accuracy which shall be achieved and on the sampling design.

Generally it can be stated that the higher the statistical accuracy which should be achieved the more samples are required and the higher the costs.
Furthermore a stratified random sampling design can reduce the number or samples required to achieve a certain statistical accuracy compared to a pure random sampling design and herewith reduces costs.

5. Costs of sampling may be higher if samples are **selected from the container** than taken from the truck. On the other hand much useful information is lost if samples are taken from the truck.

The following table presents an overview of cost issues which shall be considered before planning an analysis.

Table 12 Summary of Cost Estimation of Waste Analysis

	Planning	Sampling	Sorting	Interpretation
Cost Driver	The **cost driver** are the information needs: (Stratification for planning of waste management, Moisture Content, Density of Waste, Statistical Accuracy of Information etc..)	The **cost driver** in this phase is the number of samples which must be taken and the distance between them (if taken from the container). The costs for **personnel** clearly depend on the numbers of samples. The costs for **equipment** depend only partially on the number of samples.	The **cost driver** is the quantity of waste sorted (depending on the number of samples) and additional information needs (moisture content, density) The costs for **personnel** clearly depend on the numbers of samples. The costs for **equipment** are partially depend on the number of samples.	The **cost driver** are the information needs (see planning)
Personnel Cost	Highly qualified personnel has to do the background research and the preparation for the analysis in cooperation with the client: The data provided by the partners about **man-hours** for planning the analysis varied within a range between 40 and 200 man-hours.	Middle qualified personnel oversees the sampling and the record information. Low qualified personnel either collect sacks from households and place them on a truck or load wheeled bins on Round Collection Vehicles. If the samples are taken from the truck a tricar driver has to recoil and mix the waste in a plane surface. The supervisor checks the process.	Middle qualified personnel supervises the sampling and sorting procedure. Low qualified personnel mix the waste if it is taken from the truck sort the waste according to pre-specified waste categories. **Experience shows that it takes approximately 6 man-hours to sort 100 kg waste manually.**	Highly qualified personnel has to check the plausibility of results and has to interpret of results according to the information needs of the client and the results of the sorting process.
Equipment	Necessary Equipment is a Computer. Costs of Equipment are low	Open sided truck for refuse sacks, Refuse Collection Vehicle, Heavy Duty Bags, Litter pickers, Tarpaulin with rope, Heavy duty brushes, Shovels, Plastic Ties, Plastic Information Tags, Labels, Stationary Pad/Pens/Markers, Bacterial Hand and Face Wash, Clipboard, Box File. Labels/Data forms, Calculator, Camera(digital), Mobile phone with emergency contact numbers.	Litter pickers, Sweeping Brushes, Large table, Plastic Sheeting for table, Sharps Box, Shovels, JCB or similar for moving/mixing waste, Bins of different sizes, Heavy duty bags, Tote bags, Tarpaulin, Magnets, Anti bacterial hand/face wash, Enzyme based deodorisers Weighing platform, Data forms, Clipboard, Pens/pencils, Box file, Calculator, Sticky Labels, Camera(digital)	Computer

ANNEX V CALCULATION TABLES

ANNEX VI REFERENCES

Recommended references for sampling of collection vehicle:

ADEME (AGENCE DE L´ENVIRONNMENT ET DE LA MAITRISE DE L´ENERGIE) (1996): *Adaptation de la Méthode Modecom™ de Charactérisation des Ordures Ménagères aux Collectes Séparatives - Détermination des masses d´échantillons et recommandations pour la mise en oeuvre de l´échantillonage,* Rapport Final

ADEME (AGENCE DE L´ENVIRONNMENT ET DE LA MAITRISE DE L´ENERGIE) (1992): *Development of a Method of Analysis of Domestic Waste Composition – Study*, Angers

ADEME (AGENCE DE L´ENVIRONNMENT ET DE LA MAITRISE DE L´ENERGIE) (UNDATED): *How to assess your household waste stream*?, Procedures and Tools, from REMECOM European Measurement Network for the Characterisation of Household Waste, Angers

AMERICAN SOCIETY FOR TESTING AND MATERIALS (1992): *Standard test method for determination of the composition of unprocessed municipal solid waste*. ASTM Method D 5231 – 92 (September)

FORSHAW C., C. RUSHALL (1999): Proposal for the waste analysis in Tees Valley, Middlesbrough

KLEE, A.J., D. CARRUTH (1970): *Sample weights in solid waste composition studies*, in: Journal of the Sanitary Engineering Division: Proceedings of the American Society of Civil Engineering, August pp. 945-954

KLEE, A.J. (1993): *New Approaches to Estimation of Solid-Waste Quantity and Composition* in: ASCE Environmental Engineering Journal, Vol. 114 No2, pp. 248-261

MC CAMIC, F.W. (FERRAND AND SCHEINBERG ASSOCIATES) (1985): *Waste composition studies*: Literature review and protocol. Mass. Dept. of Envir. Mg., Massachusetts

REMECOM (1998): *How to assess your household waste stream*

RUGG (1996): *Characterization Methods*, in: LIU DAVID H.F., B.G. LIPTAK, P. A. BOUIS (Ed.) Environmental Engineers´ Handbook, Second Edition, New York

General References:

ABU QDAIS, H.A., M.F. HAMODA, J. NEWHAM, (1997): *Analysis of residential solid waste at generation sites,* in: Waste Management & Research Vol 15 No 4 pp 395-406

ADEME (AGENCE DE L´ENVIRONNMENT ET DE LA MAITRISE DE L´ENERGIE) (1996): *Adaptation de la Méthode Modecom™ de Charactérisation des Ordures Ménagères aux Collectes Séparatives - Détermination des masses d´échantillons et recommandations pour la mise en oeuvre de l´échantillonage,* Rapport Final

ADEME (AGENCE DE L´ENVIRONNMENT ET DE LA MAITRISE DE L´ENERGIE) (1992): *Development of a Method of Analysis of Domestic Waste Composition – Study*, Angers

ADEME (AGENCE DE L´ENVIRONNMENT ET DE LA MAITRISE DE L´ENERGIE) (UNDATED): *How to assess your household waste stream*?, Procedures and Tools, from REMECOM European Measurement Network for the Characterisation of Household Waste, Angers

AMERICAN SOCIETY FOR TESTING AND MATERIALS (1992): *Standard test method for determination of the composition of unprocessed municipal solid waste*. ASTM Method D 5231 – 92 (September)

AMT DER STEIERMÄRKISCHEN LANDESREGIERUNG (1998): *Siebgestützte Restmüllanalysen in der Steiermark*, Innsbruck Austria

AOO (AFVAL OVERLEG ORGAAN) (2001): *Richtlijn voor Sorteeranalyses*, Informatie Punt Afval, IPA 2001-01, Utrecht

AREY M. J. ET AL. (1993): *Use of mixed probability distributions for the analysis of solid waste generation data,* in: Waste Management & Research Vo 11, pp. 387-402

ARGUS (UNDATED): *Approach to survey in respect of amount and composition relating to residual wastes from households*, Berlin

ARGUS (1997): *Abfallerhebung Berlin 1997* on behalf of GAT (Gesellschaft für UMWELTTECHNIKEN), BERLIN

ARGUS, EDER, G. (1983): *Einflußgrößenuntersuchung zum Abfallverhalten privater Haushalte* , ARGUS on behalf of the Umweltbundesamt Berlin, report number 103 03 503/2 UBA, Berlin 1983

ARGUS, GREINER, B. (undated): *Wide Range Introduction of Separate Waste Material Collection in High Residential Areas in the City of Bremen*, ARGUS e.V. Berlin (publication pending)

BARGHOORN ET AL. (1981): *Bundesweite Hausmüllanalyse 1979/80*, Forschungsbericht 103 03 503 im Auftrag des Umweltbundesamtes, Berlin

BARGHOORN ET AL. (1986): *Bundesweite Hausmüllanalyse* 1983-1985, Forschungsbericht 103 03 508 im Auftrag des Umweltbundesamtes, Berlin

BENKERT W., (1996): *Räumliche Aspekte der Abfallwirtschaft*, in: Räumliche Aspekte umweltpolitischer Instrumente, Hannover 1996

BRIDGEWATER AV (1986): *Refuse Composition Projections and Recycling Technology*, in: Resources and Conservation, Vol 12 pp 159-174

BRITTON, P.W. (1971): *Improving manual solid waste separation studies.* U.S. EPA

BRUNNER, P.H., W.R. ERNST (1986): *Alternative Methods for the Analysis of Municipal Solid Wastes*, in: Waste Management & Research No. 2, Vol. 4, p. 147-160

CIWMB (CALIFORNIA INTEGRATED WASTE MANAGEMENT BOARD) (1999): *Statewide Waste Characterization Study: Results and Final Report*, Sacramento CA, Internet: www.ciwmb.ca.gov/publications

COGGINS, C., M. SHARATT, T. BENFIELD, (1997): *Composition of Household Waste in Luton*, in Journal of Waste Management and Resource Recovery, Vol 4, No. 1, pp. 39-46

COGGINS, C., R.W. BROWN (1995): *Waste Statistics – A Focus on Household Waste: How Much is There and What Is It?,* in Journal of Waste Management and Resource Recovery, Vol. 2, No. 3, pp 103-109

EEA (EUROPEAN ENVIRONMENT AGENCY) FISCHER C., M. CROWE (2000): *Household and municipal waste: Comparability of data in EEA member countries* Internet: www.eea.eu.int

EEA (European Environment Agency) Petersen, R., A. Ravn, N.H. Mortensen (1999): Report on an overall data model for ETC/Waste, Copenhagen Internet: www.eea.eu.int

ENVIRONMENT AGENCY (NO YEAR) PARFITT, J., R. FLOWERDEW, R. POCOCK: A Review of UK *Household Waste Arisings and Compositional Data*, Wilts UK email: publications@wrcplc.co.uk

ENVIRONMENTAL DATA SERVICES LIMITED (ENDS) Report (1999a): *Brussels Bids to Tighten Grip on Waste Statistics*, in ENDS Report, No 290, pp. 53-54

ENVIRONMENTAL PROTECTION AGENCY EPA IRELAND (1996): *Municipal Waste Charactarisation, ISBN 1 899965 32 7,* Ireland

EPA (ENVIRONMENTAL PROTECTION AGENCY USA) (1997): *Measuring Recycling: A Guide for State and Local Governments* Internet: www.epa.gov.

EPA (ENVIRONMENTAL PROTECTION AGENCY USA) (1999): *Characterization of Municipal Solid Waste in the United States* Internet: www.epa.gov

EVEN, J.C. JR. ET AL. (1981): *Residential waste generation: a case study*, in: Resources and Conservation, Vol. 6, pp. 187-201

FOERSTER, K. (1997): *Untersuchung der Einflüsse auf die Restmüll- und Bioabfallbeschaffenheit durch Einführung der Verwiegung am Beispiel der Stadt Niddatal*, in: Müll und Abfall no 8 1997 pp 452-458

FORSHAW C., C. RUSHALL (1999): Proposal for the waste analysis in Tees Valley, Middlesbrough

FRUTH F., M. KRANERT, (1997): *Durchführung und Ergebnisse einer visuellen Klassifizierung von Gewerbeabfall, Sperrmüll und kommunalen Abfällen in der Stadt Braunschweig*, in: Müll und Abfall no 1 1997 pp 14-25

GALLENKEMPER, B., H. DOEDENS, (NO YEAR): *Getrennte Sammlung von Wertstoffen des Hausmülls in*: Abfallwirtschaft in Forschung und Praxis 65: 23-37

GAY, A.E., T.G. BEAM, B.W. MAR. (1993): *Cost effective solid-waste characterization methodology*, in: Journal of Environmental Engineering (ASCE) 119, No. 4

GLÖCKL, S., (1998): *Abschätzung der Zusammensetzung von Hausmüll in Bayern,* in: Müll und Abfall (1998) 10: pp 650-655

GLÖCKL, S., (1999): *Aggregation von Daten zur Zusammensetzung von Hausmüll* in: Müllhandbuch Lfg. 7/99 1743 pp 1-14, Berlin

HAAS H.D. (1991): *Abfallentsorgung und Raumplanung – Verhaltensweisen und Lernprozesse, in: Raumplanung in den 90er Jahren*: Festschrift für Karl Ruppert (Hrsg.: Goppel K., F. Schaffer, Universität Augsburg

HAASE, H., (2000): *Methode und Ergebnisse einer Aufkommensprognose für den Restabfall zur Beseitigung im Regierungsbezirk Magdeburg* in: Müll und Abfall (2000) 7: pp 419-430

IBGE-BIM (1998): *Guide pour l'établissement d'un bilan de production de déchets ménagers*, Bruxelles

IC CONSULENTEN (1999): *Ermittlung des Verpackungsanteils in der Altpapierware in Wien 1998,* Vienna

JONES, A., S. NESARATNAM, A. PORTEOUS (1998A): *Regional Variations in Household Waste Arisings in the UK,* in: Environmental and Waste Management, Vol. 1, No. 2/ pp. 97-106

JONES, A., S. NESARATNAM, A. PORTEOUS (1998B): *Enumerating the Sources of Variation in Household Refuse Arisings Rates,* in: Environmental and Waste Management, Vol. 1, No. 4 pp. 235-242

JONES, A., S. NESARATNAM, A. PORTEOUS (1999): *Factors Affecting the Rate of Generation of Household Glass Waste*, in: Environmental and Waste Management, Vol. 2, No. 2, pp. 107-112

KIRKLIN, D.R., P.H. COLBERT (1982): *The variability of municipal solid waste and its relationship to the determination of the calorific value of RDF*, in: Resources and Conservation, Vol. 9, pp. 281-300

KLEE, A.J. (1991): *Protocol: A computerized solid waste quantity and composition estimation system*. Cincinnati: U.S. EPA Risk Reduction Engineering Laboratory

KLEE, A.J., D. CARRUTH (1970): *Sample weights in solid waste composition studies*, in: Journal of the Sanitary Engineering Division: Proceedings of the American Society of Civil Engineering, August pp. 945-954

KLEE, AJ (197?): *Design & Management for Resource Recovery Volume 3* – Quantitative Decision Making. Ann Arbor Science

KLEE, A.J. (1993): *New Approaches to Estimation of Solid-Waste Quantity and Composition* in: ASCE Environmental Engineering Journal, Vol. 114 No2, pp. 248-261

LAKE, I. R., I. J. BATEMAN, J. P. PARFITT (1996): *Assessing a Kerbside Recycling Scheme: A Quantitative and Willingness to Pay Case Study*, in: Journal of Environmental Management, Vol. 46, pp. 239-254

LANDESAMT FÜR UMWELT UND GEOLOGIE, FREISTAAT SACHSEN (1998): Richtlinie zur einheitlichen Abfallanalytik in Sachsen

LANDESUMWELTAMT BRANDENBURG (1998): *Richtlinie für die Durchführung von Untersuchungen zur Bestimmung der Menge und Zusammensetzung fester Siedlungsabfälle im Land Brandenburg*, *Teil 1*, Fachbeiträge des Landesumweltamtes Nr. 34, Potsdam

LANDESUMWELTAMT NORDRHEIN-WESTFALEN (1998.): *Leitfaden für Analysen zur Bestimmung der Menge und Zusammensetzung von Abfällen aus Haushaltungen*, Materialien Nr. 47, Essen

LATTIMER, S. (1995): *The Need for Local Composition and Arising Information for Local Authorities*, in: Journal of Waste Management and Resource Recovery, Vol. 2, No. 3, pp. 111-117

LEROY, D., J.M. GIOVANNONI, L.-T. MAYSTRE (1992): *Sampling method to determine a household waste composition variance*, in: Waste Management and Research, Vol. 10, pp. 3-12

LUCAS (LUND UNIVERSITY CENTRE FOR APPLIED SYSTEM DYNAMICS) (2000): *Assessment of different Methodologies used to determine the Amount of Packaging Waste that remains in final Disposal*

MA 48 (MAGISTRATSABTEILUNG 48) (1999): *Altstoff- und Systemmüllanalyse Wien 1997/98*, Vienna

MATSUTO T., N. TANAKA (1993): *Data analysis of daily collection tonnage of residential solid waste in Japan*, in: Waste Management & Research Vol. 11, pp. 333-343

MATSUTO T., R.K. HAM (1990): *Residential solid waste generation and recycling in the USA and Japan*, in: Waste Management & Research, Vol. 8, pp. 229-242

MC CAMIC, F.W. (FERRAND AND SCHEINBERG ASSOCIATES) (1985): *Waste composition studies*: Literature review and protocol. Mass. Dept. of Envir. Mg., Massachusetts

MORF, L.S., P.H. BRUNNER, (1999*): Methoden zur indirekten Bestimmung der Zusammensetzung von Siedlungsabfällen in:* Müllhandbuch Lfg. 7/99 1755 pp 1-16, Berlin

NEW, R. (1994): *The Essential Need for Waste Analysis, in Journal of Waste Management and Resource Recovery*, Vol. 1, No. 2, pp. 47-55

OECD/ EUROSTAT, (1992), (1994), (1996) AND (1998): *Questionnaire on waste management*

OELGEMÖLLER, D., (1999): *Empfehlungen zur Vorgehensweise bei der Durchführung von Sperrmüllanalysen*, in: Müllhandbuch Lfg 7/99 1722 pp 1-8, Berlin

PARFITT, J., R. FLOWERDEW, P. DOKTOR (1994): *Socio-economic Variables in Household Waste Modeling: Two Case Studies*, CSERGE Working Paper, WM 94-02 CSERGE, Norwich

PARFITT, J., R. FLOWERDEW, R. POCOCK (UNDATED): *A Review of UK Household Waste Arisings and Compositional Data* on behalf of UK Environment Agency, R&D Technical Report P240

POHLMANN, M., (1991): *Bestimmung von Menge und Zusammensetzung häuslicher und gewerblicher Abfälle als Voraussetzung abfallwirtschaftlicher Planung*, in Müll und Abfall: Vol. 23 no. 12 pp. 796-808

REMECOM (1998): *How to assess your household waste stream*

RHYNER, C.R., B.D. GREEN (1988): *The predictive accuracy of published solid waste generation factors*, in: Waste Management and Research, Vol. 6, pp. 329-338

RICHARDSON R.A., J. HAVLICEK (1974): *An analysis of seasonal household waste generation*, in: Southern Journal of Agricultural Economics, Dec 1974, pp 143-155

RICHARDSON R.A., J. HAVLICEK (1978): *Economic analysis of the composition of household solid wastes*, in: Journal of Environmental Economics and Management, Vol. 5, 103-111

RIJKSINSTITUUT VOOR VOLKSGEGEZONDHEIT EN MILIEU RIVM (2001): *Onderzoek naar de fysische samenstelling von het Nederlandse huishoudelijk restafval*, Resultaten 1998 en 1999, page 5, Bilthoven, NL

RUGG (1996): *Characterization Methods*, in: LIU DAVID H.F., B.G. LIPTAK, P. A. BOUIS (Ed.) Environmental Engineers´ Handbook, Second Edition, New York

RUSHBROOK, P.E. & BALL R. (1988): *Improved estimation of waste arisings using limited sample sizes* in: Waste Management and Research, Vol. 6 pp.35-44

SÄCHSISCHES LANDESAMT FÜR UMWELT UND GEOLOGIE (1998): *Richtlinie zur einheitlichen Abfallanalytik in Sachsen*, Materialien zur Abfallwirtschaft, Dresden

SALHOFER, S., B. RAUSCHER (1998): *Sichtungen und Sortieranalysen als Kontrollinstrument der kommunalen Abfallwirtschaft* in: Österreichische Wasser- und Abfallwirtschaft Vol 50 No 7/ pp. 169-179

SCHARFF C, G. VOGEL (1991): *Oberösterreichische Systemmüllanalyse*, O.ö. Umweltakademie des Amtes der o.ö. Landesregierung, Wien

SCHARFF C. (1991): Entwicklung und Anwendung von Methoden zur stoff- und warenorientierten Analyse von Abfallströmen, Wien

SCHARFF C., G. VOGEL (1990): *Forschungsberichte zum Projekt Biotonne Salzburg, Teil 1 – Planungsgrundlagen und Ergebnisse der Salzburger Müllanalysen 1988-90*, Amt der Salzburger Landesregierung, Wien

SCHARFF, C., (1991): *Entwicklung und Anwendung von Methoden zur Stoff- und Warenorientierten Analyse von Abfallströmen*, Dissertation Vienna

SCHARFF, C., G. VOGEL (1994): *A Comparison of Collection Systems in European Cities*, in: Waste Management & Research Vol. 12 No 5 pp 387-404

SEATTLE PUBLIC UTILITIES: (2000): 1998/99 *Residential Waste Stream Composition Study*, internet: www.ci.seattle.wa.us/util/solidwaste/

SPIES, H., (1999): *Amtliche Abfallstatistik*: in: Müllhandbuch Lfg 7/99 1702 pp 1-14, Berlin

STATE OF OREGON, (1999): Department of Environmental Quality: *1998 Oregon Solid Waste Composition*, Portland

TCHOBANOGLOUS, G., H. THEISEN, S.A. VIGIL (1993): *Integrated solid waste management: engineering principles and management issues*, McGraw-Hill

TERASHOMA, Y. ET AL (1984): *Optimum sampling of municipal solid wastes, Conservation and Recycling*, Vol. 7, Nos. 2-4, pp. 295-308

UBA (UMWELTBUNDESAMT GER) EISENBÄTTER, R., (NO YEAR): *Richtlinien über Siedlungsabfalluntersuchungen aus der Sicht des Bundes*

UNI 9246, (*ITALIAN REGULATION ON SAMPLING FOR WASTE ANALYSIS*)

VOGEL G. (1976): *Verpackungsanteil am österreichischen Hausmüll*, Schriftenreihe Verpackungsforschung, H.2,2.A, Österreichisches Institut für Verpackungswesen, Wien

VOGEL G. (1980)*: Die Systemsammlung von Altstoffen – Ein Verfahren zur Abfallverwertung*, in: Schriftenreihe des Institutes für Technologie und Warenwirtschaftslehre der Wirtschaftsuniversität Wien, Bd. 1/1980

VOGEL G. (1985): *Zwischenergebnisse der Forschungsprojekte im Rahmen des Wiener Abfallwirtschaftskonzeptes, Teil 1*: Modellversuch Planquadrat, innere Studie für die Stadt Wien, Magistratsabteilung 48, Wien

VOGEL, G., Scharff, C.(1986): *Der Einfluß des Konsumverhaltens der Wiener Bevölkerung um die Weihnachtsfeiertage auf Menge, Zusammensetzung und Verpackungsanteil des Hausmülls*, in: Schriftenreihe Umweltschutz und Ressourcenökonomie, Wien

WUTTKE, J., (1999): Bundesweite Gewerbeabfalluntersuchung, in: Müllhandbuch Lfg 7/99 1742 pp 1-13, Berlin

YU, CC AND MACLAREN V (1995): *A comparison of two waste stream quantification and characterization methodologies*. Waste Management & Research Vo. 13, 343-361

ZWISELE, B. (1998): *Statistische Gesichtspunkte bei der Auswahl von Stichprobeneinheiten für Haumülluntersuchungen*, in: Müllhandbuch: contribution serial number: 1713 (p. 1-18)