1 Analysis of Waste Composition and Characterisation of Wastelines

2 Basics

Waste is analysed in order to get information about its composition concerning components and chemical and physical characteristics. These analyses cover:

- The composition regarding
    - particle size
    - components
    - utilization/hazardous material.

  This analysis uses sieving and sorting by hand.
- The chemical/physical characteristics of the individual sieving fractions and substances and of the whole sample, e.g.
    - specific weight
    - water content
    - free airspace
    - water capacity
    - pH-range
    - gross and net calorific value
    - incandescent heat loss
    - salinity
    - content of hazardous material
    - plant nutrients content

  are analysed from selective samples in the laboratory.

This list must be minimized or maximized according to the specific requirements. Factors such as the treatment of the waste, the recycling or the (thermal or biological) conversion determine the scope of the analysis to a great extent.

In general the sift and sorting analyses of waste is generally part of a waste management database of either a specific collection area or firm. It can also serve as a means of determining the efficiency of waste collection systems and waste processing plants. That is why, it is wise during the collection of data from a waste collection area or a firm, to simultaneously establish the data from the waste containers which are being used. Furthermore, this information forms the basis of estimating the efficiency of the collection and transport systems in use.

Basic container data include:

- the gross container weight
- volume percentage
- the content weight
- the frequency/availability of collection (door-to-door-collection)
- the frequency of use of bottle banks and special containers, e.g. for recoverables (source separation)

The municipal authorities or the management of a company require waste analyses:

- to establish waste quantities (e.g. recoverables/remains) and based on this
- to help choose suitable treatment plants (waste processing facilities) or parts there of and their dimensions.

Therefore, waste analyses contribute not only towards an increasing efficiency in the methods in use, but also of equipment (e.g. mills, sieves, conveying equipment, transport) and/or methods of work (separation of certain recoverables, degradable material, etc.)

The way of waste product data is collected will depend mainly on the structure of the material to be tested. The size of the parts plays a decisive role. Thus, at a sorting line it is impossible to separate household waste of less than 40 mm in diameter. Also, separating a mixture of industrial waste will be problematic due to the heterogenuity of the materials.

Therefore, in the following we are going to distinguish between useful methods of waste treatment (e.g. screening, sorting), including the respective spot checks, and practical steps.

3 Choosing a representative spot check

It is very important to select samples from the defined rangerandomly. Only those samples meeting the statistical requirements guarantee comprehensive and representative data.

The exact determination of the sampling range and area or where the sample is to be taken, results respectively from the specific requirement to the sorting (e.g. degree of purity from separately registered waste sources, the composition of mixed waste, the degree of skimming from certain recoverables, assorted container sizes, etc.).

Household waste and similar waste from industry consist of non-separated waste as well as source separated biowaste and recoverables depending on the collection system. In general they are collected either in containers at site or in a bring scheme system of bottle ranks for example, which allow only specific items to be inserted and are of limited capacity. Waste collection runs normally on a regular basis from house to house or between collection points. In each case the quantity of collected waste from a collection area will represent the basic entirety from which the random sample will be taken (0.5%-1.0% of the weight per collection for door-to-door collections; up to 10-15% of the weight of containers at collection centres for recoverables, depending on the distance from one collection centre to the next).

Seasonal differences in the quantities and composition of the collected waste can be registered with at least four sorting analyses a year. This could be reduced to two analyses if e.g. the minimum and maximum quantities per season are known. In this case the samples should be taken during maximum periods.

Regarding household waste and industrial waste similar to household waste it is advisable to know the structure of the area (housing density, use) based on statistic data, e.g. number of inhabitants, proportion of green areas, number of flats/apartments per house, proportion used by industry, etc. The information can usually be obtained from the data bases run by the state authorities responsible for statistics.

Furthermore, the container sizes, the frequency of collection, the system of managing recoverables and similar, play an important role. This information can normally be obtained from the authorities responsible for waste management or direct from the contractors.

A mixed sample from the area is taken, possibly considering:

- considering the urban structure on the basis of a statistical unit (e.g. number of apartments per building, green area, etc.) is taken, i. e. only containers from the respective urban structure are taken for the samples, or
- considering the specific use of the area/source (e.g. mixed areas: industry/housing) is taken.

The sample represents one collection tour on the day of collection. Common sense would suggest that the basis for sample taking should be the collection area, since the sample must be taken on the day of normal waste collection. The range of sample taking is limited. Due to technical reasons, one team (4 – 8 persons according to the diversity of groups requiring sorting, equipped with sifting machine and conveyor belt), can only process a maximum of 1 000 – 1 200 kg of waste each working day.

Either a refuse truck with a suitable tipping mechanism is used for collection, or the waste is transferred into smaller containers (e.g. 1.1 m³), which then are transported by compartment trucks with loading ramps, or by exchanging (empty against full) containers or by emptying of big containers (e.g. for glass and paper) from one waste lorry onto another one (e.g. with divided loading area).

The following shows four examples for the management of sampling for door-to-door collection:

I. Amount of the sample

Mixed sample considering the urban structure (e.g. in small areas).

The area has got 100 000 inhabitants producing 300 kg of mixed collected waste per person and year. A sample quantity of 0.5 weight percent (weekly collection) makes 2 880 kg for the spot check.

Quantity 100 000 people x 300 kg per person and year x 0.5%

52 weeks per year

= 2880 kg.

II. Number of dust bins

At an average bulk weight, which is calculated for 240 l MGB from 120 kg/m³ and a filling level of 80%, there are 125 waste containers to be collected per interval. Three working days for sorting have to be planned based on a sorting capacity of 1 000 kg/day.

Example for an urban srtucture:

- Structure I: 1-2 apartments/buildung = 75%
- Structure II: 3-4 apartments/building = 15%
- Structure lll: >4 apartments/building = 10%.

According to the urban structure (percentage) samples are taken from all categories of the area. From structure I 94 containers, from structure II 19 and from structure III 13 containers have to be collected. They are chosen at random according to the container list (site with house number) and respectively collected at one tour.

III. Sample based on the urban structure (e.g. in large areas)

Contrary to a) the samples are separately taken for each urban structure. At the collection day only containers of one specific urban structure in the area are chosen. The quantity of waste to be collected depends to a great deal on the homogeneity of the respective structures at site and ranges from approx. 1 000 kg-2 000 kg for each urban structure and sorting date. About 40 to 90 containers of 240 1 MGB and mixed waste must be collected.

IV. Sample considering the origin/source (e.g. industrial waste similar to household waste)

According to the use of the buildings only containers from industrial companies are collected. The collected sample quantity depends on the homogeneity of the industrial area.

It is approximately 1% of the waste quantity or higher as the enterprises producing industrial waste similar to household waste range from offices to selling companies and trades to small industrial plants.

In addition to factors influencing the composition of waste at the door-to-door collection (urban structure. container sizes, ratio of industrial enterprises. etc.) there are a number of special requirements for the bring system (generally, containers for recoverables):

- how far it is to the nearest container site (inhabitants per site)
- how easy or difficult it is to get there (vehicles. pedestrians)
- how they fir into the general infrastructure (shops, public transport stops. etc.)
- how they can be controled (illegal waste disposal).

These conditions should be known before the sampling plan is made. The conditions mentioned are as important as the urban structure itself because they may lead to conditions which are different from or in addition to those of the collection system.

Tab. 1: Influences on sampling for sieving and sorting analysis for different kinds of household waste and collecting systems

influence factor	collect systems			bring systems	
	recyclable	organic	mix and rest	green waste	recyclable
container size	yes	yes	yes	no	no
season	no	yes	(yes)	yes	no
urban structure	yes	yes	yes	yes	yes
ratio of green spaces	no	yes	(yes)	yes	no
accessibility to container site	no 1)	no 1)	no	yes	yes
surroundings of the container site	no 1)	no 1)	no	yes	yes
density of container sites	-	-	-	yes	yes
in brackets: take notice of connection to other collect systems					
dashes mean „no relevance“					
1) Differences occur only between containers assigned directly to one household (e.g. single-family or semidetached houses) and collective used containers					

4 Container identification data

For the research on waste disposal systems, embossing a container identification data helped to inspect the provided container volume per citizen in dependency of the waste removal cycle, size of the container and collection system as well as identification data pertaining to the tour plan.

The following problems are present in the background:

- The size of the container is too small i.e. the waste is collected at too long intervals:
    - Secondary disposal (e.g. highway/autobahn recreation areas),
    - In multi-container systems (e.g. dual-barrel-system, Mekam) bad division or
    - Dirtying locations (e.g. container for recyclables).
- Containers too big and the collection intervals too small:
    - Undesired materials, e.g. bulky waste, demolition waste, bush cutting, which usually have a separate disposal system, find their way into the containers.
    - The general utilization ratio is low.
- The capacity of the collecting vehicles:
    - Specific weight of the waste (payload, permissible maximum weight),
    - Number of containers to be filled per tour (capacity, specific weight).

5 Random sampling

The main unit for the choice of samples for container identification data is the total number of waste-containers used in that area, i.e. for example all MGB with a capacity of 120/240 l or all valuable-material-containers for glass and paper at the regular collecting time. If the influence of the area-structure has to be taken into account (building developments, green areas or industrial sectors etc.) then it would be advisable to use a sub-division of the main unit for evaluating the interesting parameters.

A very good example here is the bio-waste container system for the garden area (as compared to the total catchment area) which represents a deciding factor for the capacity of the container necessary.

In the case of house-to-house waste collection it is advisable to collect between 5 and 10% container identification data samples from the whole investigation area for a statistical coverage of the samples. This would mean for example that for a collection trip of 120/240 l MGB mixed waste, if a total of 1 200 existing containers, the contents of at least every sixtieth of the 120 and 240 l containers should be investigated. The selection of the containers to be recorded can as a rule be made from lists available with the regional corporations/local authorities or container lists of the waste collecting companies. If data specific to the area structure is to be compiled then land allocation plans and building development plans will also have to be taken into account, in order to select all houses with gardens for example. If no such data is available, the classification of the samples will have to be made after inspecting the waste-collection area.

Seasonal deviations in waste quantity should be considered while choosing the time to carry out the investigation throughout the year. Investigations should be preferably carried out at a time when maximum waste is produced (e.g. autumn and winter in the case of bio-waste). According to this waste-quantity statistics, the container capacity for a particular kind of waste at a specific time of the year can be determined quite accurately.

Selecting a suitable sample for container identification data of bring systems (e.g. container for valuable materials) can be done likewise. Special attention should be paid to the quality of the location and the environmental structure. The number of containers to be inspected in this case should not be under 20% of the total number of existing containers; an inspection of all the containers in the course of waste removal is mostly possible in this case.

6 Data compilation and evaluation

The fill level in the container (scale) and its total weight is determined (spring balance up to MGB 240 l, in the case of larger containers, changing the containers and weighing them separately or with a wheel load weighing machine). The following are recorded in pre-drafted form:

- Location (e.g. name of the street/house number),
- Type of container and its volume (e.g. 110 l-round barrel, glass container 3 m³),
- Type of waste (e.g. residual waste),
- Fill level (measured from the top rim of the container up to the surface of the contents),
- Total weight of the containers (gross weight) and
- Other location data, as for e.g. accessibility, cleanliness (only depot container).

5.1 Collection systems

The most practicable method for the house-to-house systems proved to be, while collecting at regular intervals, to start at a particular point and then work out the whole area systematically with the help of an area map. Attention should be paid to the following:

1 The team doing the weighing is generally slower than the collecting vehicle ==> therefore they should start earlier than the collectors.

2 In areas where the waste is collected at a later time (normally the collecting begins between 6 a.m. and 7 a.m.), the containers are also put out shortly before the collectors are due ==> do not start too early, not all the containers may be put out.

The weighing team should comprise of at least three people, the output would then be about 50 MGB/h. Two people lift the container with the help of a spring scale attached to a rod, the third person notes down the gross weight and records all necessary data. In the case of containers with a nominal capacity larger than 240 l the weight should either be recorded with a wheel load weighing machine or the containers should be changed.

A practical way of getting the data for a graph depicting the fill level of the respective containers is to carry out a liquid output with water. (The gap to the fill level 10 cm). Containers that have an opening at the side are lined with a thin plastic sack. The average weight of 5-10 empty containers can be used as relatively accurate net weight to determine the weight of the waste and its specific weight. (ref. Fig. 3.1 for curves).

To calculate the provision quota for the house to house collection, all provided containers are counted during the collection tour. The ration of the containers provided to the total number of containers available (see list of containers) is given in %.

Utensils necessary (containers having a capacity of up to 240 l):

- Writing board and pencils
- City maps and road maps
- Forms
- Ruler
- Spring balance with rod and hook
- Torch (depending on the season)
- Umbrellas and raincoats
- Vehicle (for long distances)
- Counter for piece goods (provision quota)

Tab. 2: Conversion diagram for the filling level (examples collect systems)

Polynom third grade: $Y = A(3) * X^3 + A(2) * X^2 + A(1) * X + A(0)$ (Y in [l], X in [cm])						
Round bins and MGB	Size and type of container					
	Round bin		**Big waste container (MGB)**			
coefficient	50 l	110 l	80 l	120 l	240 l	Biowaste bin
A(0)	49,8267	110,3108	90,0168	118,8441-	238,5643	88,0823
A(1)	-1,0508	-1,5135	-1,3920	-1,8545	-2,7715	-1,1699
A(2)	0,00649	0,00168	0,00325	0,00725	0,00045	-0,0057
A(3)	$-3{,}9230^{-05}$	$3{,}5489^{-07}$	$-3{,}2051^{-06}$	$-2{,}1402^{-05}$	$3{,}0536^{-05}$	$8{,}0194^{-05}$

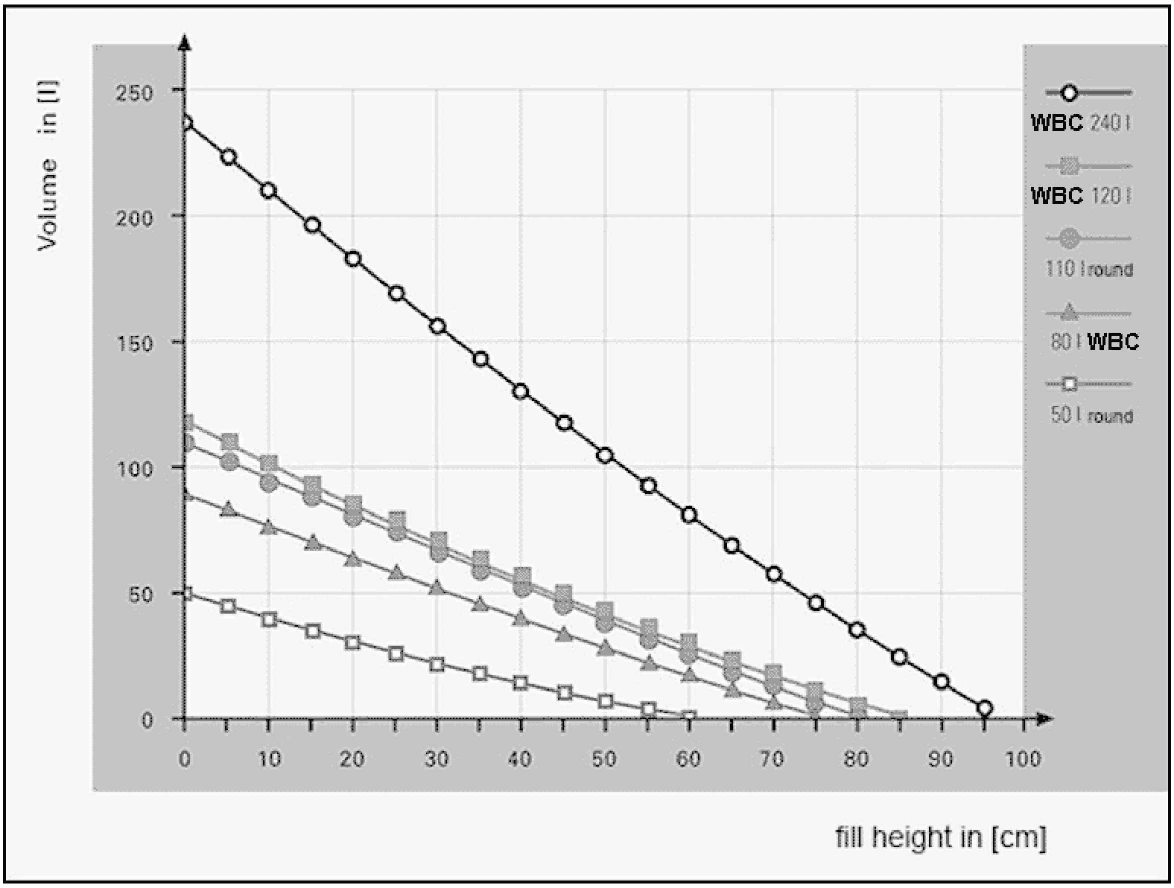

Fig .1: **Fill level graphs of different waste containers (collect systems)**

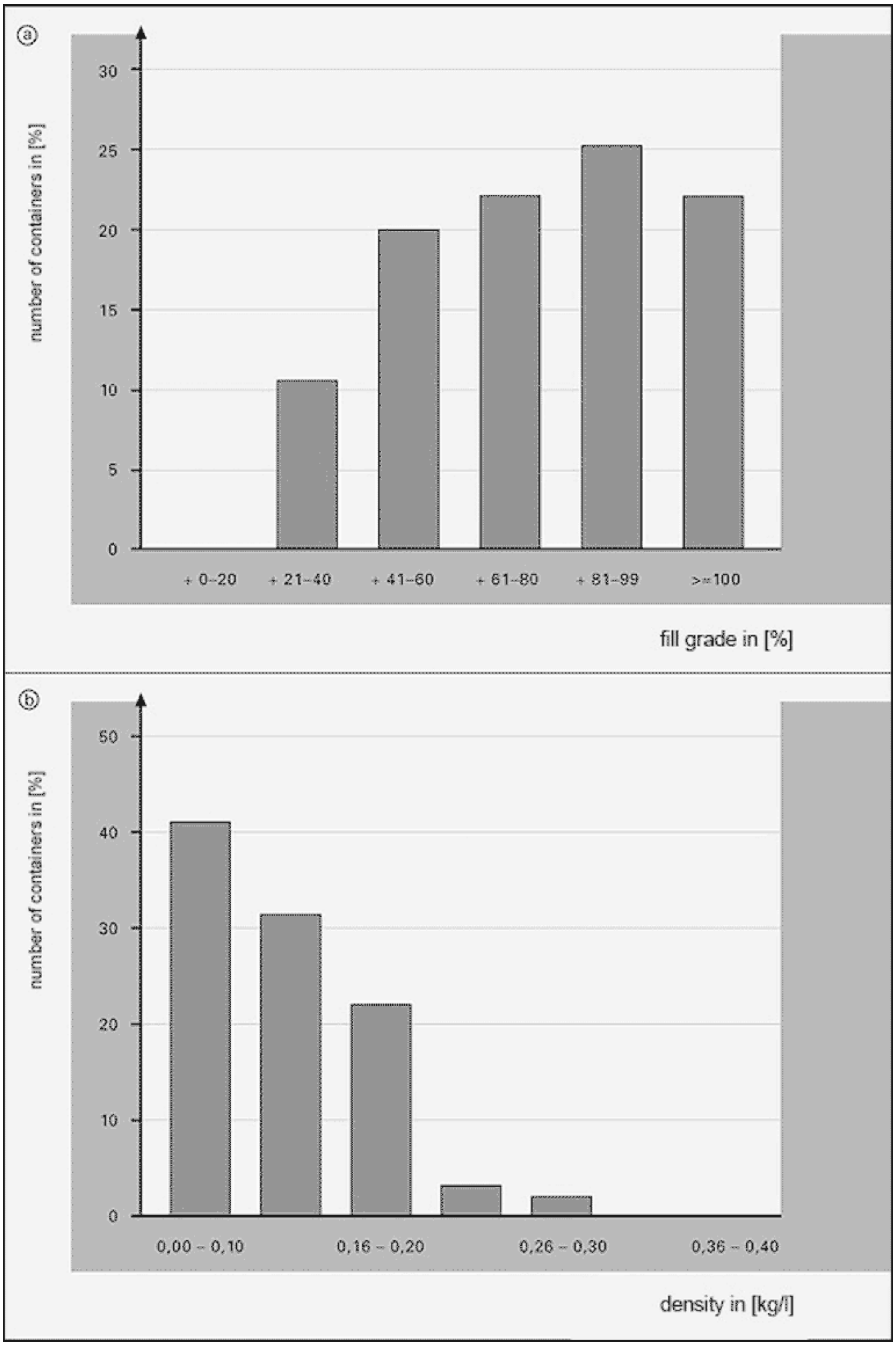

Fig. 2: Evaluation examples for container identity data (collect systems)

5.2 Bring systems

In the case of Depot containers the fill-level graphs can be best drawn from the measurements calculated from the construction details. The weight of the waste can in this case be determined only by emptying out the contents on to a separate vehicle.

From the volume of the waste calculated from the average of the fill-level graphs of the respective container types (compare Fig. 1 and Tab. 2) and the net weight of the waste the piled weight is calculated. The filling grade of the containers is obtained from the ratio of the waste volume and the volume of the containers, it is given in vol.-%. Tab. 3.

Tab. 3: Examples for container identity data (Bring systems)

Location	No. of containers	Filling grad %	Last emptied days ago d	Associated inhabitants	Area structure [1)]	Environmental position	Results of the collection kg/(cap a)	Total weight kg
Paper containers (3 m³)								
1	2	90/95	8	740	1.1	central	40,4	330
2	1	100	8	740	2.1	border, extreme	40,4	160
3	1	100	4	710	2.2/2.3	central	31,3	450
4	1	100	4	710	1.3	central	31,3	250
5	2	95/95	4	1 000	2.2/2.3	border, extreme	12,3	470
6	1	50	7	1 150	3.1	border, extreme	6,2	135
7	2	100/100	10	1 000	2.3/3.2	border, extreme	12,3	305
8	1	110	7	610	1.2	central	14,1	290
9	2	100/100	7	1 390	3.1	border	10,1	620
10	1	45	7	700	1.1	central	13,3	285

Loca-tion	No. of con-tainers	Filling grad %	Last emptied days ago d	Associ-ated inhabi-tants	Area struc-ture [1)]	Environ mental position	Results of the collec-tion kg/(cap a)	Total weight kg
11	1	100	7	780	1.1	central	11,3	280
12	2	100/50	7	1 080	3.1	Border, extreme	9,6	240
13	1	55	14	260	1.2	central	11,3	155
14	1	100	7	550	1.2	central	14,2	245
Containers for Glass-/Tins (3 m³)								
1	1	75	7	710	1.3	central	35,4	530
2	1	60	7	710	2.2/2.3	central	35,4	395
3	1	100	21	550	1.2	central	17,5	660
4	1	70	28	260	1.2	central	22,8	475
5	2	105/105	20	1 390	3.1	border	11,7	1 285
6	1	120	28	700	1.1	central	21,4	800
7	1	80	21	740	2.1	Border, extreme	27,2	470
8	1	50	7	740	1.1	central	27,2	290
9	1	50	14	1 000	2.3/3.2	Border, extreme	37,7	345
10	1	120	21	1 150	3.1	Border, extreme	12,2	770
11	1	50	7	780	1.1	central	26,2	355
12	2	60/100	7	610	1.2	central	14,4	770

1) Area structures: 1.1 Centre , rural(dense building development) 1.2 Centre, rural (not so densely developed) 1.3 Centre, urban (densely developed) 2.1 Centre, urban (not so densely developed) 2.2 housing development, rural (not so dense) 2.3 housing development, urban (dense) 3.1 mixed development, rural (trade/housing) 3.2 mixed development, urban (trade/housing)

7 Sieving and handsorting analysis

The following chapter describes the steps of the analysis of waste composition. There are two steps or ways:

- sieving
- sorting by hand

Fig. 3 shows the steps for the individual sorts of waste. You can see the way of sift and selection analyses of mixed collected household or residual waste after the recoverables and! or biowaste was sorted.

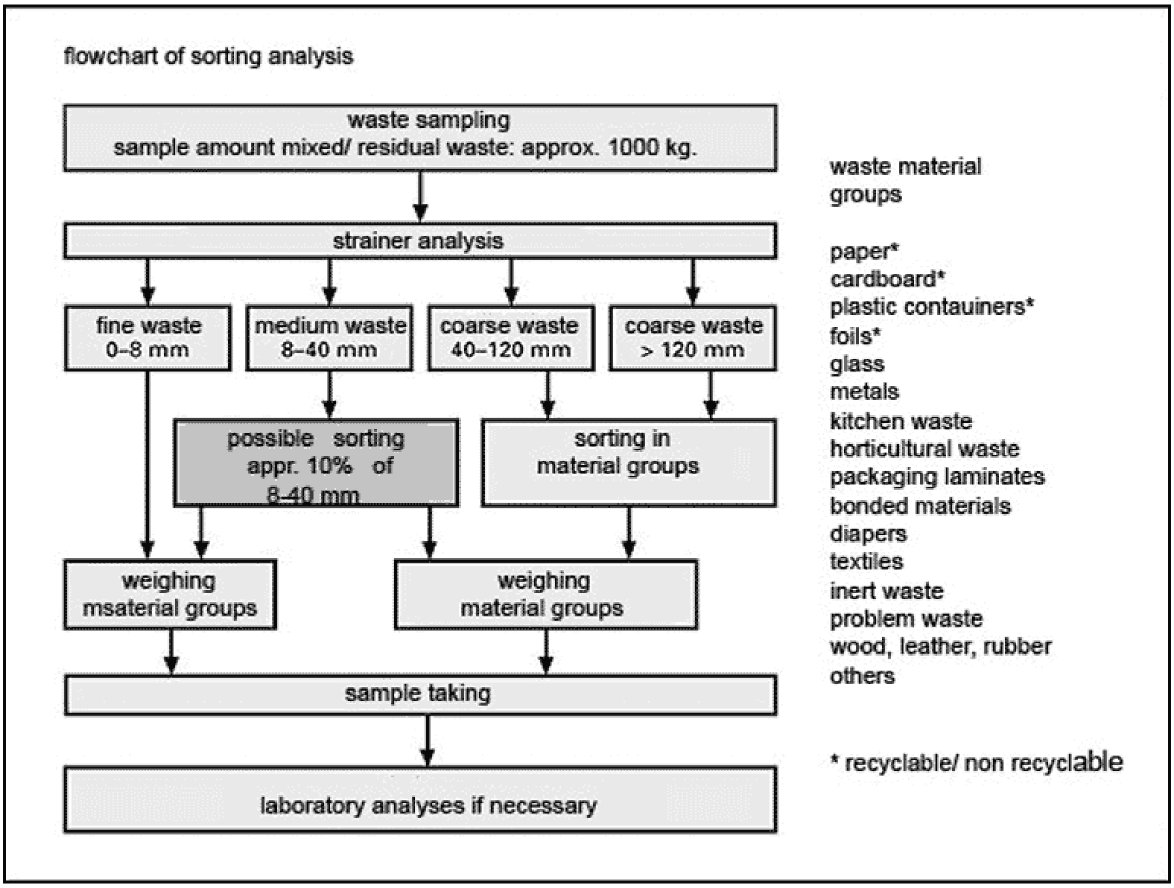

Fig. 3: **Plan for a sieving and sorting analysis of assorted household waste products or residual waste from waste separation systems**

7.1 Sieving

Samples are sifted in order to separate the waste components into fractions, which may easily be sorted by hand, or to combine some components in one sift. Generally, particle sizes of 8 mm, 40 mm and 120 mm are used in the sieves. Only particles > 40 mm are suitable for sorting by hand. As the personell wears special gloves the workers may have problems grasping smaller parts.

Similar to the analyses of household waste there are the following sift fractions:

- small particle waste (0-8 mm)
- medium particle waste (8-40 mm) and
- coarse waste (40-120 mm and > 120 mm).

In general, the small and medium particle waste fractions are so homogeneous that a mixed sample is useful for detailed data such as bulk weight, water content, incandescent heat loss, calorific value, etc. If necessary, it is possible to sort a sample of the fraction 840 mm (approx. 10 wt.-%) into different groups. Sieving fractions of > 40 mm can easily be sorted by hand. The number of material groups to be selected depends on the aim of the analysis or the sort of waste.

For waste with a high content of small particles it is useful to start with a sieving analysis. This refers mainly to relatively dry household waste (mixed waste, mixed recoverables, residual waste) as well as industrial waste similar to household waste, depending on the aim of the analysis.

For mixed collected recoverables sieving can be useful as industrial sorting plants select some waste components by sieving anyway and take them to the group of residual waste. A final sorting of a sample is advisable in order to find out specific concentrations of components. On the other side, sifting may be redundant in case only some specific components have to be sorted. This has to be decided on from case to case. Pure recoverables (e.g. glass or paper) are only checked for possible foreign materials. Therefore, sieving is not necessary. As biowaste is usually relatively wet, sieving makes sense only for some samples. Also, in this case only the anorganic components are of interest. Therefore, a size fractioning of sieving is reluctant.

Flat as well as drum screens can be used for sieving. The sort and throughput of the screens should make sure that all samples of one day (for household waste approx. 1200kg) can be sifted and sorted by the same team at the sieving line, including final sorting of the fraction 8-40 mm if necessary.

The sifting site should be wind and rain protected. Attention must be payed when the waste is put onto the screens. All bags and containers must be opened and emptied. In order to avoid loss of water content, the samples for the analyses and for final sorting have to be taken immediately after sifting. Otherwise the analyses would show incorrect data (concerning weight and water content).

All weight data have to be reported, including those of samples and refuse taken. Only in this way exact weighing results (sift line) can be guaranteed.

Equipment:

3 screen

4 container for the small particle fractions < 40 mm

5 sufficient or rustic foils or awnings for the fractions > 40 mm

6 shovels and pitchforks

7 scales

8 forms and pens

9 containers for the samples (for the laboratory)

10 conveyor belt to transport the waste (depending on the size of the screnn)

11 face masks for the personell (in case of dry waste)

12 working gloves

Tab. 4: Sorting categories

Positive selection of mixed household waste [1)] and residual waste	**Negative selection biowaste**
Paper: • publications • clean paper • residual paper (without toilet paper) Card/cardboard paper Plastics: • foils • containers Miscellaneous Glass (colour separated) Metals: • magnetic • non-magnetic Packing composites Material composites Textiles Disposable nappies Minerals Wood, leather, rubber, horn, bones Problematic waste Remnants at the belt	All foreign materials, such as: • metals • plastics • glass • and all other non-composting categories
1) including industrial waste similar to household waste	

Weighing Sift fractions	Weighing Categories

Sorting Approx. 10% of 8-40 mm	Sorting in Categories

Small particle waste 0-8 mm	Medium particle waste 8-40 mm	Coarse waste 40-120 mm	Coarse waste > 120 mm

Sort of waste	**Sieving**	**Sorting by hand**
Mixed household [1)] and residual waste	yes	yes
Mixed recoverables	optional	yes
Pure recoverables and biowaste	no	yes

7.2 Sorting by hand

Only sorting by hand makes it possible to find out about the exact composition of the waste. Depending on the sort of waste the number of categories to be sorted will vary a great deal. Generally, the main issue during the sorting analysis is whether the waste can be utilised. But also the contents of problematic waste and/or pollutant contents could be of interest. Depending on the sort of waste the fractions are sorted negatively or positively.

7.2.1 Sorting method

In the positive sorting all interesting categories are separated by hand and weighed separately. This method is used first of all for mixed collecte household waste, residual waste after the sorting out of recoverables and/or biological waste, industrial waste similar to household waste but also for mixed industrial waste. In these cases the rest represents either all non-utilizable waste or the so-called "vegetabile" rest which could be composted.

A negative sorting is always useful if the checked waste has got a very homogeneous composition. This refers e.g. to recoverables collected in separate categories and biowaste. Monocharges, too, of industrial waste should be sorted in this way. In this method the rest sorted out is the selected fraction of recoverables and biowaste.

Of course, depending on the target of the analysis there are mixed methods of positive and negative sorting, too.

For example, at the sorting of the contents of glass depot containers not only glass is separated from foreign materials but at the same time the glass is sorted into special categories such as colours and broken/unbroken glass.

In general, a group of six to eight people in one shift are able to sort up to 20 fractions (mixed household waste). Each person can manage between one and four fractions depending on the number of categories.

Tab. 5 provides a survey about the way of sorting different sorts of waste. In Fig. 4 an example for the arrangements at a machine sorting mixed collected household waste is shown.

Besides hand sorting the exact weighing of the individual fractions is extremely important. It is advisable to have one specific person for the weighing list (the changing of personnel may result in mistakes, e.g. differing names for the categories). It is essential that all categories and all rests (sweepings) are weighed. The scales should be checked at least every work day. The people at the scales have to know the technology of the different scales. In the weighing forms all gross and tare results have to be registered carefully (mistakes are possible during reporting).

Tab. 5: Sorting fractions for various kinds of waste

Waste fractions	Sieving	Sorting by hand	Optical classing
mixed household waste [1)] and residual waste	yes	yes	no
mixed recoverables	optional	yes	no
Pure recoverables and biowaste	no	yes	no
commercial and construction waste	optional	yes	yes
bulky waste	no	no	yes
[1)] including commercial waste similar to household waste			

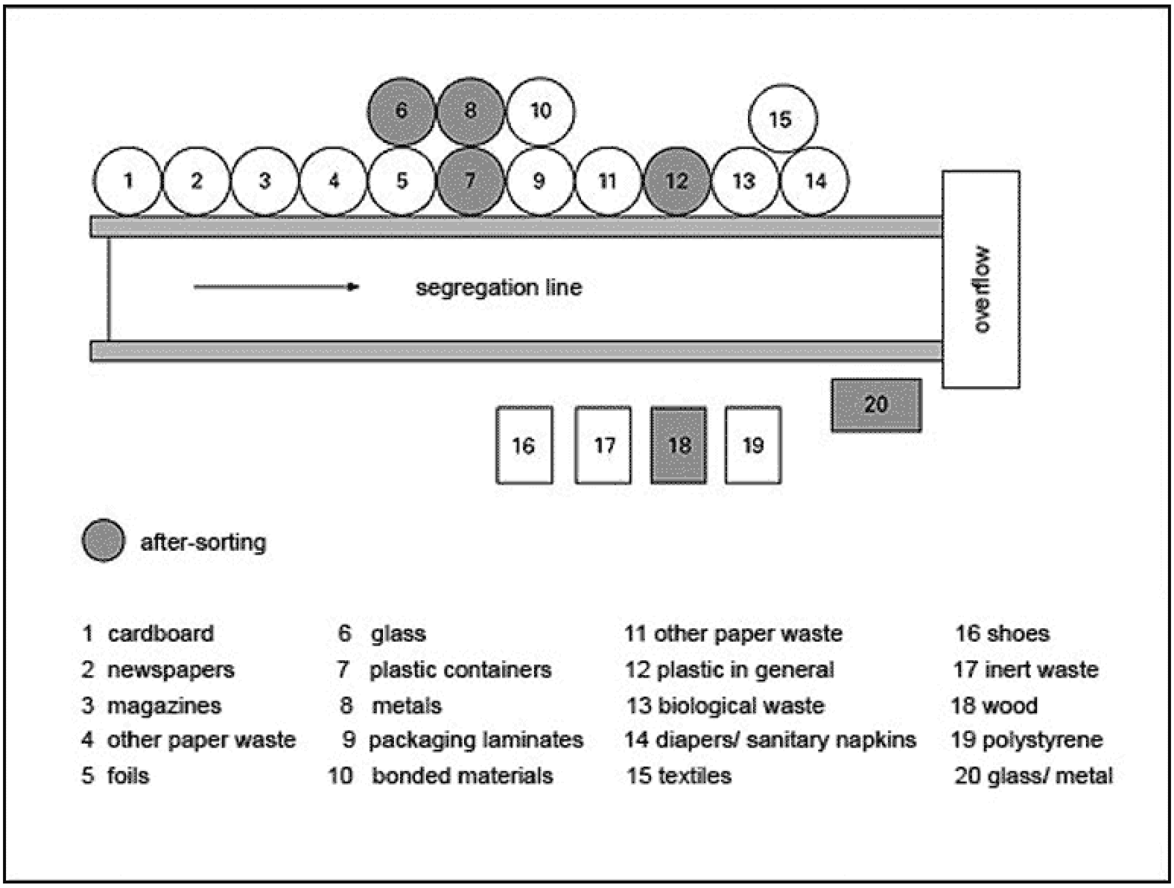

Fig. 4: Arrangements for the sorting of mixed collected household waste

7.2.2 Necessary equipment

I. sorting

- sorting belt or table e.g.
- sorting containers (120/140 1 MGB): The number of containers should be double the number of sorting fractions
- sorting bowls (contents 5-20 1): about 5, used for quantitatively small categories (such as problematic waste) or for the second sorting (e.g. metals into magnetic and non-magnetic ones)
- for the end of the sorting belt (depending on the sort of belt):
- Rustic foil bags with a capacity of about 150 to 200 I and connections to the belt or
- 240 I MGB (not compatible to various sorts of belts) or
- wooden or plastic boxes
- felt marker (indelible ink) to write the tare results on the sorting containers
- crepe or packing tape in case special marking is necessary
- magnet for the second sorting of metals into magnetic and non-magnetic ones
- large, sturdy foil covering for waste to protect against rain or sun (water contents)

II. weighing

- at least two bag scales up to 150 kg (MGB-weighing) or spring scales a small electronic scale plus batteries for low weights up to 10 kg

III. tools and electrical equipmet

- shovels (both flat ended and pointed), pitchfork, hooked pitchfork, hand brush and broom
- complete tool box
- for electrical sorting belts
- Cable drum (e.g. 220 V)
- Cable distributor (e.g. 220/380 V) plus (if necessary) cable adapter (e.g. 32 A to 16 A/380 V)

IV. Health and safety

- Health and safety
- Eye protection for sorting glass
- face masks for dusty environment
- safety helmets to be worn when presents in unfamiliar premises
- strong leather working gloves (rubber if necessary when working with wet waste)
- rain jackets and cold weather jackets (depending on time of year and weather)
- safety boots and sturdy clothing
- hand washing paste and hygiene paper
- first-aid boxes. Addresses and telephone numbers of doctors to be placed on site

V. office equipment and stationery

- stationery (pencils, ball-point pens, rubbers, sharpeners, etc.)
- calculators and (if necessary) laptop plus floppy discs, battery charger, batteries for analyses at site
- forms for the different sortings (weights, etc.) and collective lists for the collection of the samples taken in the morning, plus city maps

Vl. taking samples for chemical analysis

- sample containers with lids and PE bags (e.g. samples of the fraction < 40 mm)
- foil sample bag sealing equipment
- scoop for collection of samples in laboratory (flour scoop)
- strenghtened foil for the manufacture of a mixed sample

VIl. transport of the sample (e.g.)

- truck for the transporting of the sifting mashine, conveyors, scales, sorting containers, etc.)
- minibus for the transport of personell
- vehicles suitable to take and collect the samples
- refuse-truck (without drum as this will crush the sample)
- truck with loading ramp of 1.1 m^3 containers (discharge of waste from bins)
- lorry with platform and divided loading area (e.g. for samples from depot containers –> dis-charge)

At the site of sorting or at least near it there should be a building with washing facilities, toilets, and rest rooms.

7.3 Optical Classing

If manual sorting cannot be done due to the composition of the waste (e.g. bulky waste) or because a very large number of control samples are required (e.g. commercial waste) and it is necessary in spite of this to obtain a substantiated overview of the composition of the waste to be inspected, then the method of optical classing also called sighting is used.

In the following an example of how a commercial waste sighting is conducted is described as the optical classing according to different categories of matter is most conventional for this kind of waste. The method described here can be likewise used for other kinds of waste as well.

The aim of a commercial waste sighting is to determine the waste quantity, the composition and if possible the origin. Besides the type of Vehicles needed for collecting this waste can also be defined. As a rule data is collected on each of the following:

- The waste producer,
- Total volume of the waste delivered,
- Net weight of the waste delivered
- Material composition of each volumetric content.

It is advisable to sub-divide the delivered charges into three categories which will give information as to whether a grading according to material groups can be conducted in a mechanised facility and what time and efforts are needed for this.

- “good gradability“: higher percentage of one material, hardly contaminated, dry,
- “average gradability“: various materials, average contamination, dry and
- “bad gradability“: many different materials, very mixed and contaminated and/or wet.

Tab. 3.6 can serve as example for a form that can be used on location for estimating the volumetric portions of material groups, dividing them according to their gradability and allocating their loading according to weight. From the number plate of the vehicle, date and time, the particular Weight-certificate and if included in the inspection, the questionnaire on the basis of which the driver had been interviewed on the origin of the waste, can be located. Knowing the make of the vehicle one could conclude the degree of compression of the waste and a statistics on the vehicles could be compiled.

Experiences show that while calculating the weight of the waste (net) per delivery from the apparent weight of each of the material groups and their estimated volumes, an error of much less than 10% of the weighed quantity is generally possible. This ensures that the collected data is quite accurate and can be used for waste management planning.

Tab. 6: Example of a form for optical classing of commercial waste

<table>
<tr><td colspan="3">COMMERCIAL WASTE SIGHTING (Project)</td></tr>
<tr><td colspan="2">Date/Time:</td><td>Serial number:</td></tr>
<tr><td colspan="2">Number plate:</td><td>Section:</td></tr>
<tr><td colspan="2">Gradability</td><td>Vehicle</td></tr>
<tr><td>O good</td><td>(higher percentage of one material, hardly contaminated, dry)</td><td>O Waste transporter</td></tr>
<tr><td>O average</td><td>(various materials, average contamination, dry)</td><td>O Container having ...... m³</td></tr>
<tr><td>O poor</td><td>(many different materials, very mixed and contaminated and/or wet)</td><td>O pallet
O other</td></tr>
<tr><td colspan="3">Material group in vol.-%</td></tr>
<tr><td></td><td>PAPER</td><td>PACKAGING MIXTURE</td></tr>
<tr><td></td><td>CARDBOARD</td><td>WOOD</td></tr>
<tr><td></td><td>PLASTICS</td><td>PALETTS</td></tr>
<tr><td></td><td>TEXTILES</td><td>MINERAL LIKE</td></tr>
<tr><td></td><td>GREEN WASTE</td><td>HOUSE-HOLD WASTE LIKE</td></tr>
<tr><td></td><td>OTHER ORGANIC</td><td>OTHER</td></tr>
</table>

Tab. 7 shows an example of an inspection conducted to clarify the large limits of variation of the apparent weight calculated from the known volume and the weighed quantity of the commercial waste in the transport vehicles and containers. The apparent weight of the complete load in each case is shown.

Tab. 7: Specific weight of the mixed commercial waste [kg/m³] in the transport vehicle i.e. container. Examples from inspections carried out in two German districts in 1991

Waste transporter, container	Gradability			No. of measurements according to gradability		
	good	average	poor	good	average	poor
Container with a press	159 (84-	148 (68-	229 (108-	14	14	14
Container without a press	116 (26-	106 (46-	131 (38-	31	37	89
Waste transporter(with a pressing plate)	162 (55-	288 (223-	274 (110-	3	6	17
Pallet transporters	140 (40-	133 (96-	129 (70-	7	4	7

( ) within brackets: scatter range

Necessary Utensils:

- Writing board and pencils,
- Forms,
- Working clothes (Safety shoes etc.) and
- Umbrellas and raincoats (according to weather).

8 Implementing a commercial waste analysis

Following is a description of the process to be chosen for determining the composition of commercial waste. Fundamentally possible analytical methods are critically observed once more and a method for sighting the commercial waste is described.

A basic problem is defining the term commercial waste. The types of waste to be included in this definition depend on the reason for the commercial waste analysis. If it is mainly aimed at detecting input materials for a house-hold incinerating plant or another facility for treating house-hold waste then the target will be commercial waste resembling house-hold waste as defined in TA - municipal waste. Product specified waste should be included even for determining the recycling potential. If the total quantity is needed then building rubble, sewage sludge and even agricultural waste in a broad sense of the term should also be added. Tab. 8 shows which kind of waste is to be considered for which purpose. From this it becomes clear that the choice of method finally depends on the purpose of the analysis.

Tab. 8: Reason for the choice of the analysis method and the waste categories concerned

	Dimensioning house-hold waste treat-ment plants	Determining the evaluation quota	Commercial waste register	Dimensioning Recycling paths
Commercial waste re-sembling house-hold waste	x	x	x	x
Trade waste	x	x		x
Construction rubble		x		x
Production specific waste		x	x	x
Agricultural waste		x		

8.1 Choosing the process

Basically two different methods should be followed for determining the composition of commercial waste:

Investigation at the source

- Questionnaire
- Site inspections

Investigating the mode of collection

- Sorting
- Optical screening

If the methods have already been discussed then a comparison should be made here. Tab. 9 clearly shows that an ideal method does not exist.

Tab. 9: Comparing the efficiency of different methods for analysing commercial waste in view of compiling a complete set of data

	A	B	C	D
Performance feature	Sorting selected deliveries	Commercial waste screening	Questionnaire covering the whole area (register)	Inspection of selected sites
Embossing annual quantities and the following conclusions				
Trade waste	--	--	+	--
Commercial waste resembling household waste	-	+	0	-
Product specific waste	-	+	0	-
Construction rubble/excavations	--	+	-	-
Building and demolition waste, mixed building waste	-	+	-	-
Separately collected valuable materials from industrial waste	--	--	+	0
Special waste	--	--	+	0
Waste from private dumps	-	+	--	--
Agricultural waste and other similar wastes	-	+	--	--
Waste disposed in private plants	-	+/-	+	0
Differentiating the recorded data				
Listing according to categories	++	+	+	+
Listing according to categories	++	++	0	+
Production pattern at the sector level	-	+	++	-

	A	B	C	D
Performance feature	Sorting selected deliveries	Commer-cial waste screening	Question-naire cov-ering the whole area (register)	Inspection of selected sites
Production pattern at the sector level	-	++	++	-
Recycling pattern	--	--	++	0
Delivery pattern	--	++	--	0
Degree of separate collection	-	++	0	0
Material reparability	++	++	--	0
Time and effort for sorting	-	++		
Basis for counselling at the company level	-	+	+	0
Basis for counselling at the sector	-	+	+	-
Reliability/Representativeness of the recorded data				
Waste types	0	+	+	0
Waste fractions	++	+	-	-
Company level	+	-	+	++
Sector level	-	0	+	
District level	-	+	0	-
Amount of work				
Amount of work	0	0	+	0

Evaluation scale:	++	"very well possible"
	+	"well possible"

	0	"neutral"
	-	"hardly possible"
	--	"not possible"

The data obtained from optical sorting of commercial waste offers a high degree of integrity and certainty. The reasons for this are that

- A total survey is conducted for a particular time period,
- Almost all the components can be separated,
- It is possible to assign these components to its producers to a large extent
- It provides information to sortability, recyclability and the supply pattern

Due to the high man-power involved in this kind of sorting it is limited and can therefore be applied only to house-hold waste resembling commercial waste. To random inspection. In addition to this it becomes clear from Tab. 8 that the data analysis with respect to supply and recycling pattern is very limited.

Generally, no reliable information can be obtained from these other two methods applied at the source unless followed by sorting or sighting. Without being backed up by an optical sorting for example, evaluation from questionnaires can lead to wrong assumptions as shown in Fig. 3.5. The depiction shows that the mixed waste was over proportioned by the producer in favour of composite materials and plastics. The uncertainness of the persons filling out these questionnaires reflected in the results especially with regard to the constitution of the waste components. Using qualified people to determine the waste components as in the case of screening for example would definitely give more accurate data.

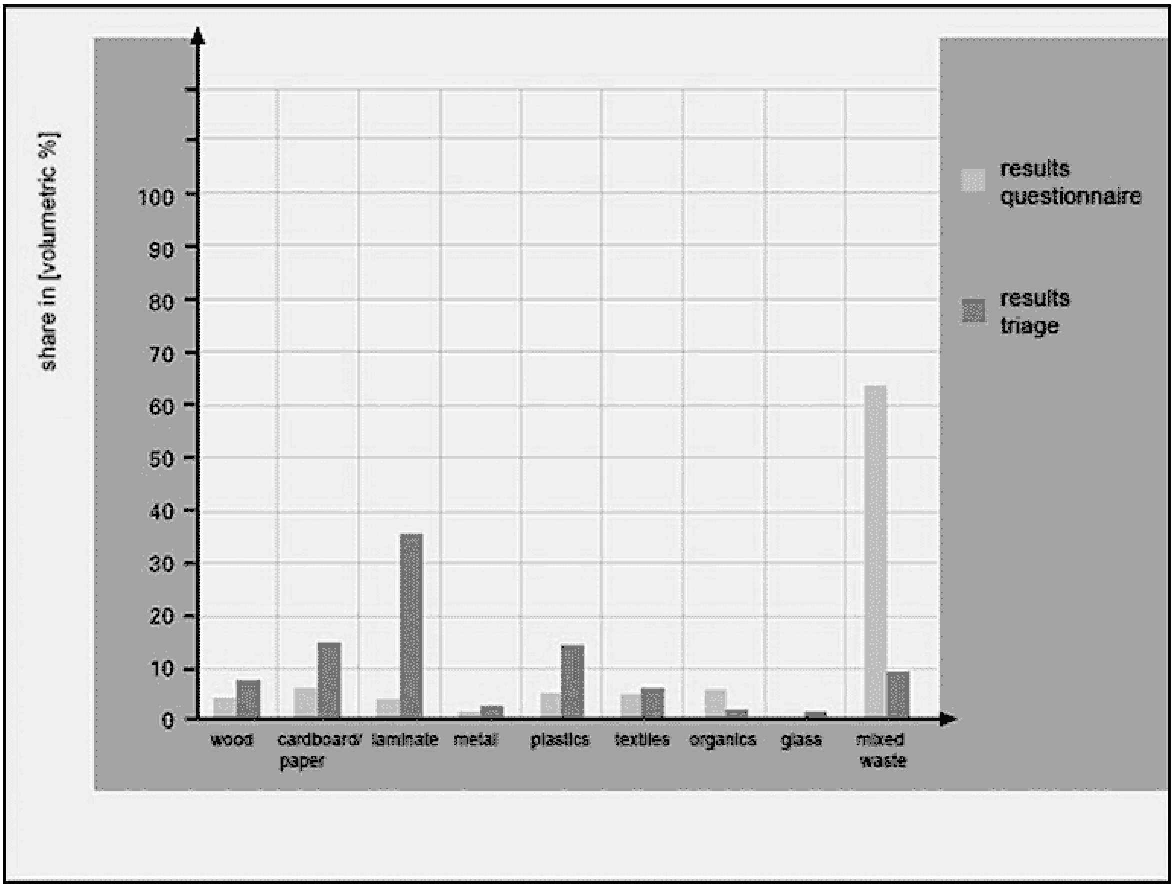

Fig. 5: **Comparison of data from a commercial waste screening to that evaluated from questionnaires conducted in an administrative district (as in MU Rheinland-Pfalz, 1993)**

Optical sifting of commercial waste is described here bearing the above in mind and processed for application (chapter 3.5.2 Procedure for commercial waste sifting).

8.2 Procedure for commercial waste sifting

The sifting of commercial waste is methodically based on an estimation of the component volumes through an optical inspection. This is then converted into weight proportions using empirical formulations. There are large deviations in the data obtained by this procedure as compared to those obtained by manual sorting but is relative considering the large sample quantities.

According to Fig. 6 the procedure of a commercial waste sifting can be sketched as follows.

Work Steps		Quality Management
site reconnaissance	investigation of specific frame conditions of the site, client wishes, staff and time management	
statistical pre-inquiry	frame data of the waste disposal area regarding waste quantity, rates, economical structure	
list of waste producer	compilation of the main waste producer according to landfill client file, analysis of delivery declaration or other documents	
data collection whilst delivery	acceptance of all deliveries beyond house and business waste collection, acceptance of vehicle identification, deliverer, deliverer branch, waste file classification according to delivery declaration	*methodology suit to local conditions and questions, in-depth briefing of staff*
scale	waste net weight, quoted waste volume	
visual inspection	classification according to waste types and groups of materials, separation according to pressed and not pressed materials, additional indication of resource concentration and possibility of sorting grade, check of waste volume, estimation of volumetric waste composition according to pre-set groups of materials (visual classification), specifics, e.g. high water content	*experienced staff as the case may be in-depth briefing of staff*
data input	input of all numerical data into the software, encoding of all alphanumerical data (branches, deliverer, producer etc.) and also input into the software	*plausibility check, data correction*
conversion	waste type specific conversation of volume and weight proportion by mathematical approximation procedure	*mathematic founded solution, independent from subjective valuation*
database evaluation	volume and weight proportion of waste composition according to waste types, producer branches, individual producers etc., origin of waste, type of delivery, resource concentration and possibility of sorting grade, extrapolation for the whole waste disposal area and annual quantities	*plausibility check, data correction*

Fig. 6: Commercial waste screening procedure

In order to determine feasible and economically advantageous quantities a period of one to two weeks is chosen for the sifting. Every single commercial waste supplier should be included as excluding any specific supplies (loads) would lead to incorrect and incomplete data. The sifting itself should be carried out by two or more people depending on extensive it is. Each person works on one delivered truck-load of waste (pouring).

Owing to lack of time and money it is not possible to do a double check on the assessment. Systematic errors therefore exist. These can only be held at a minimum if the assessors are self-critical, well motivated to work accurately and are experienced.

The sifter waits for the waste delivery at the location where the waste is unloaded and tries to make a rough estimate of the composition of the waste while it is being poured out of the sacks.

He should be in possession of standardized forms that not only have questions that will later help to clearly identify the transport vehicles and their assignment but also contains questions pertaining to the quality and quantity of the waste to be sifted. Specific standard forms for each sifting suited to the local conditions should be available (Fig. 7).

Questions should be asked for example on the sortability of the waste, the transport vehicle type, the container volume and the filler content of the delivery containers. Even the waste producer is recorded so that specific waste counselling is possible in the companies producing the waste. Finally the volume percent of the material groups present in the delivered waste is estimated.

Special characteristics such as higher water content, pressed loads or differences in the case of construction waste should be considered.

Industrial waste survey
September- October 1994

Technical University Berlin
workgroup Environmental statistics

☐ North ☐ South ☐ Schwanebeck ☐ Wernsdorf

Date ______ auditor ______

time												
licence plate number												
	Berlin		external		Berlin		external		Berlin		external	
delivery company												
Con/Press/Umleer/Son	C	P	U	S	C	P	U	S	C	P	U	S
waste volume		m^3	filling grade %			m^3	filling grade %			m^3	filling grade %	
producer of waste/ sector												
material groups	%	comments			%	comments			%	comments		
1. packaging												
	cardboard		plastics		cardboard		plastics		cardboard		plastics	
	wood		styrofoam		wood		styrofoam		wood		styrofoam	
	metal		glass		metal		glass		metal		glass	
2. household- like waste												
3. other plastics												
4. bulky waste												
5. wood/ furniture												
6. upholstered f./mattresses												
7. metals												
8. horticultural waste												
9. Construction waste												
10. renovation waste												
11. glass												
12. paper												
13. textiles												
14. waste specific for production												
15. other-/ non-classifiable waste												
comments												

Fig. 7: Example of a form for commercial waste analysis

After completing the sifting the data is evaluated. (compare chapter 5.3 Evaluation of commercial waste siftings/screenings).

The weight of waste in each waste transport vehicle, recorded at the disposal plant and the total weight calculated from the waste volume, the sum of the estimated volume percent of each of the material groups, the respective apparent densities and eventually other corrected factors are used as basic. The weight recorded at the site and the calculated total weight doesn't usually tally as there are errors in each of the starting values.

The aim of the evaluation now is to try and bring the starting weight as close as possible to the calculated total weight by varying the erroneous starting values. Very often many iterations are necessary. The material groups altered in the course of the iteration, are to be viewed critically a tallying the recorded starting weight with the calculated total weight does not inevitably mean that the values of the different material groups are also correct. Even computer supported evaluation of the sifting does not change this fact as it is based on the manually evaluated data. Sifting of commercial waste therefore remains an estimation procedure.

Through sifting the waste quantities and their subsequent sorting it was established that the results of the sifting matched those of the sorting. The margin of error by the volume estimation as compared to that of the sorting with respect to the individual material groups was approx. 10%. The total survey over a defined period of time levels out this error when compared to the limited sample quantities of the sorting.

8.3 Evaluation of commercial waste siftings/screenings

The following formula is used for evaluating commercial waste siftings:

Calculated total weight [kg] = Σ weight of the material groups [kg]

In which the weight of the material groups [kg] = V (apparent volume) [m³]   Volume percent [%] / 100   apparent density [kg/m³].

The apparent volume is defined as the volume taken by the waste in the delivered waste containers. This can easily lead to misunderstandings as we are not actually dealing with a poured volume here. It would be reasonable to adjust the meaning of the definition to the procedure and to denominate apparent volume with the poured volume of waste in the following.

The estimated proportional volume of the individual material groups is considered as "volume proportion" while calculating the material group weight.

The apparent density here does not denote the packing density of the material groups in the delivery containers. In fact it is related to the apparent volume and therefore characterizes the density of the respective material groups in the poured and not compressed waste body.

According to definition and using the above formula, the weights of the material groups sum up to the calculated total weight.

It becomes clear from the formula that even an accurate estimation of the volume percent of the individual material groups does not inevitably lead to an accurate weight of the specific material group. Both apparent volume and apparent density are quantities that cannot be accurately determined and therefore prone to errors.

8.3.1 Erroneous quantities

Determination of the volume percent is based on an estimation and therefore it is obviously erroneous. It is difficult to define the limits of this error. The experience of the person conducting the estimation plays a major role here. In the case of commercial waste sifting/screening it is assumed that the error caused by the volume percent estimation is relatively small compared to that of the apparent density.

When the delivery container is being emptied, the volume of the waste quantity generally increases.

There fore the method which is sometimes used to simplify the evaluation of commercial waste screenings/siftings, by which the apparent volume is presumed equal to the delivery volume (container volume x filler content), is incorrect. Depending on various factors it is possible that the waste expands following the emptying process, which would increase the waste volume to several times its volume at the time it is delivered.

The degree of expansion of waste volume through the process of emptying depends on the following features:

- Structure of the waste (Form and geometry of the specific material groups);
- Specific character of the observed material groups (expandability, water binding ability)

And other factors such as:

- The period for which it has already been stored in the delivery containers);
- Mode of delivery (dumper or compaction container);
- Method and speed of the emptying process;
- Topography of the area on which the waste is emptied on (horizontal surface, sloped surface).

In order to get closer to the apparent volume quickly and rationally the expansion factors of the commercial waste sifting/screening were determined. These factors describe the expanding tendency of the specific material groups when a particular volume of waste is emptied from a dumper on to a surface. It will of course be necessary to correct the expansion factor as soon as the delivery is done by a waste transport vehicle or in compaction containers.

For an accurate determination of these factors one should investigate the influences of the above mentioned parameters on the expansion. Thus the only factors not taken into account while evaluating a screening are the moistness of the waste and the water binding ability of the individual fractions. However these are precisely the influencing factors that define the expandability of frequently occurring material groups such as paper, cardboard and foils. The interaction between the different material groups with respect to their expandability has also not been considered. If material groups with a higher apparent density come to lie on material groups that basically tend to expand strongly, then the expansion of these groups will be clearly smaller.

15 different material groups are listed on the sample form for commercial waste screening (Fig. 7). So a combination of 15 different material groups would be possible.

If these material groups were to be systematically investigated on how pairs of material groups influence the apparent density of each other, 105 investigations would be necessary. This is impossible! In any case it would be reasonable to check the reciprocal influence of some common and critical material groups.

Further expansion influencing factors such as the method and speed of unloading the waste will have to remain unconsidered since it is very difficult to record the quantitative influence of these qualitative factors.

Ultimately one should not forget to consider what is practised when more information is demanded for getting better results. Generally the sifter/screener has only little time to survey a commercial waste delivery. Therefore the amount of information that can be recorded is also limited. If too much is asked, it is inevitable that the quality of the data will suffer. The extra investment of time and man-power is therefore questionable.

The apparent density is closely related to the expansion factor. With the degree of expansion the apparent density of a material group also decreases and moves independent of its specific weight (density of solids) towards zero with extreme expansion. The upper limit forms the specific weight of a material group.

Theoretically even this can be overcome as in the case of compaction container packed Styrofoam. Generally the apparent density of a material group is very much lower than its specific weight.

If a material group reaches its determined average expansion during unloading, different apparent densities could result depending on various factors. The geometry of the waste particles plays an important role in this case too. Fig. 8 shows the average values and variation ranges of the apparent densities of different material groups. The range depends on pre-compacting, water content and mixture.

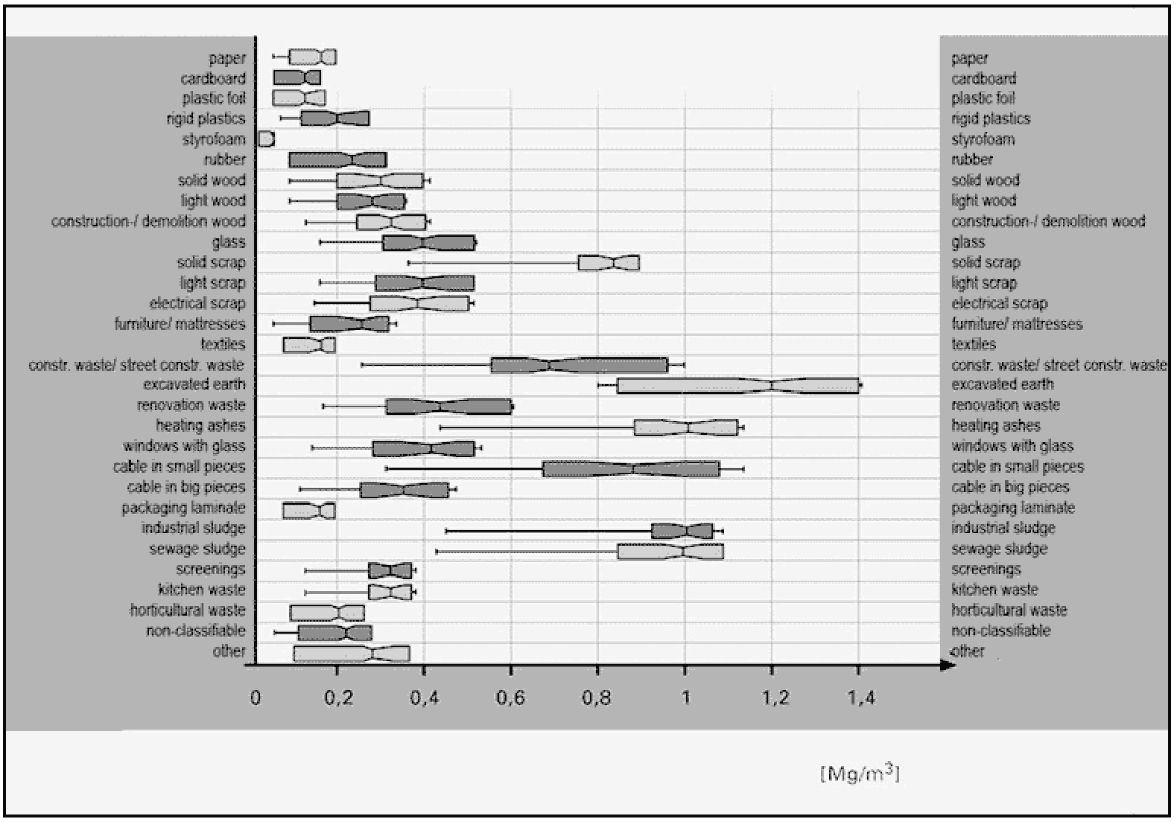

Fig. 8: **Apparent densities of waste types and material groups from commercial waste screenings; least number of random samples = 25 (Source: Diverse papers of the universities of Stuttgart and Essen, not published)**

8.4 Calculated results of the evaluation

For evaluating a screening form it is necessary to work out a row of data. Besides information on the origin of the waste and its producer, the volume proportions and the apparent densities are also necessary to calculate the weight of the material groups.

8.4.1 Calculated evaluation

The algorithm is reduced to the following process by neglecting all the influencing factors mentioned previously:

First of all the given data is worked out using the formula already given for calculating the weights of the material groups (compare chapter 5.3 Evaluation of commercial waste siftings/screenings).

According to this the weight of the specific material groups is calculated as:

Formula 1: $M(i) = AV \cdot VP(i) \cdot d(i)$

with

M(i)	Weight of material group
AV	Apparent volume
VP(i)	Volume proportion
d(i)	Apparent density

Before the first material-group weights can be calculated, the apparent volume has to be determined. The formula used for this was compiled according to following considerations.

Each material has its own expansion factor and will have to be according to its proportion, considered for determining the apparent volume. The equation for determining the apparent volume is derived from the following initial equations:

This means:

given:

DV = The volume of waste in the vehicle at the time of delivery

presumed:

DVi = Volume of a particular material group at the time of delivery i

EFi = Expansion factor of a particular material group i

VPi = Volume proportion of a particular material group i sought:

AV = Apparent volume of the total waste

AVi= Apparent volume of a particular material group i

Formula 2: $$DV(i) \cdot EF(i) = AV(i)$$

Formula 3: $$AV \cdot VP(i) = AV(i)$$

Formula 4: $$DV = \sum_{i=1}^{n} DV(i)$$

from Formula 2:

Formula.5: $$DV(i) = \frac{AV(i)}{EF(i)}$$

Formula 3 and Formula 5 integrated into Formula 4:

Formula 6: $$DV = AV \cdot \sum_{i=1}^{n} \frac{VP(i)}{EF(i)}$$

Formula 3 integrated into Formula 2:

Formula 7: $$DV(i) = \frac{AV \cdot VP(i)}{EF(i)}$$

Equation for determining the apparent volume:

Formula 8: $$AV = \frac{DV}{\sum_{i=1}^{n} \frac{VP(i)}{EF(i)}}$$

The expansion factor used in this equation can be taken from a data pool. Constants that have various influences on the expansion factor and could change them can be described and listed in this pool. The expansion factors have not been corrected up to now since any measurement data or experience values of the influencing factors that could change the expansion factor, are available.

At first the mass of the individual material groups are determined from the calculated apparent volume AV, the presumed volume percent VP(i) and the selected apparent densities. Then the material group weights are added to the calculated total weight. Finally the absolute and the percentage deviation of the calculated total weight from the initial weight are derived.

The formula for determining the material group weight is always used as often as required through manual iteration, by which either apparent density or apparent volume can be changed by the user before each calculation. This way a close approximation to a plausible result can be obtained step by step.

Automatic iteration is actually an approximation method. Basically one can iterate till the percentage deviation has reached zero.

If the calculated total weight is smaller or greater than the starting weight in the first set of calculations, the apparent volume will be changed in the next iteration. At first it is decreased or increased by 5%. Then the calculation is repeated with this altered apparent volume and the material group weight and the total calculated weight is again derived. If the iteration condition (calculated weight = starting weight) is not fulfilled then the material groups are listed according to the material group weights in the next step.

The apparent densities are altered one by one by 10% for example. We start with the material group having the largest weight proportion. Again the material group weights and the calculated total weights are derived. If the iteration goal is not achieved, then the calculations are repeated till the apparent density of the fraction having the smallest weight has been changed. If the approximation is still insufficient, the apparent volume is altered again by 2%. Then the apparent density appropriate to the material group weight is altered by 10% in each case.

It becomes clear that the iteration process is limited to manipulating the apparent density and the apparent volume. Mistakes in presuming the volume per cent are not taken into consideration and expansion factors which cannot be considered as constant values are not changed.

In order to also include these points as variable factors in an iteration, investigations which will lead to markers, probable values and presumed ranges, are necessary. Only after that can more complex iteration algorithms be developed. This procedure shows a marginal error of +5% when compared to manual sorting.

Extrapolating the random sample results are done quarterly or half-yearly depending on how often the investigations are conducted. For determining the specific material group quantities of specific waste disposal areas within a specific time, the calculated mass percent of the material groups is multiplied with the total waste quantity within this time. While deducing the representative components of commercial waste per time unit and the numerous individual compositions one should take into consideration that commercial waste distribution is not normal but logically normal.

The calculation method shown here represents a modified version of the one developed by Barghoorn et al. It gives us values that are independent of the poured waste volume. No possibilities for double checking are therefore offered here.

For deducing the weight percent, the volume percent is converted to weight percent for each randomly selected vehicle according to the following method.To get a clear assignation of volume and weight values, material group i (e.g. cardboard) and vehicle type (e.g. kipper) should be fixed.

The equation applied is:

Formula 9: $$MP_i = \frac{d_i \cdot VP_i \cdot AV}{AM}$$

where

MP_i	Mass percent of the material group i [%]
VP_i	Volume percent of the material group i, presumed from the poured waste [%]
AM	Total waste mass of the load [Mg]

AV
Total waste volume in the vehicle [m³]

d_i
average volumetric weight of the material group deduced from the volumetric load of the vehicle load in which more than 80% of the volume is occupied by the material group. [Mg/m²]

BARGHOORN et al. offer approximate values for average volumetric weights d_i.

Since the densities are assumed values, the sum of the weight percent of a vehicle load is not inevitably 100%. The weight percent of the individual vehicle loads will therefore have to be converted to get the sum of 100% (rule of proportion).

8.5 Check lists for the allocation of commercial waste analysis

The preceding chapters explained the conditions under which a commercial waste screening would be a reasonable method of obtaining information for determining the quantitative composition of commercial waste. Therefore emphasis is only on these methods in the following chapters.

8.5.1 Points to be considered during a commercial waste screening

The advantage of a commercial waste screening is that samples can be taken over the whole year. The data for the quantity of commercial waste for a time unit is collected and totalled. This means for example that all the loads delivered at the waste processing plant in one single day is screened. The sampling should not be singled out according to branches or mono batches. For the random sampling over the year following points should be considered:

- That data should be collected for at least one to two weeks (Monday to Saturday) for the whole day. This will ensure a representative cross-section for a particular time of the year since commercial waste mostly follows a weekly cycle.
- School holidays and weeks with public holidays should be omitted from the plan since the collectivity is otherwise not represented.
- While planning the analysis one should check whether firms or establishments operating seasonally exist in the area. The time of the year should be chosen accordingly and repeated analysis should be carried out (e.g. construction firms that are closed down for the winter).
- Those transporters that mix the commercial waste in order to optimize transportation should also be recorded. If this is done to a large extent then arrangements should be made that this is not done during the analysis period in order to ensure that the allocation of the waste and its producers is correct.
- Those waste deliveries that cannot be allocated to the surveyed area should be sorted out carefully in order to also assign a sample size to a particular project area.

After considering these factors the analysis should be done over one or two weeks at least.

Apart from taking samples a characterization of the environment should also be done. Following data are relevant:

- The number of relevant waste disposal plants,
- Time variation curve of the commercial waste quantities of at least the last twelve months,
- Statistics allocated to the enterprises and firms,
- Demolition waste statistics,
- The type of containers and transport vehicles used in the surveyed area (e.g. compaction container or containers where the contents are loose and not compressed),
- List of all waste transporters,
- Time variation curve of the daily frequency of the supply vehicles,
- Number of private suppliers.

This information is necessary for planning the time and duration of the analysis as well as determining the man-power size for conducting the analysis on one side and for extrapolating the data at the sector level, at the level of the individual firms, and for the whole year.

Further care should be taken that only reliable and trained people should be employed for conducting the screenings to reduce and systemize errors. Enough time should be calculated for selecting and training the people.

Well planned forms will prevent errors and later on facilitate the data input. Adequate time should be given in advance for this. Since each survey area will have specific conditions it will be difficult to work with common forms. It will be absolutely necessary to draft forms to suit specific cases.

8.5.2 General procedure

Commercial waste screening can be divided into three blocks:

- Data collected in advance and preparing the screening
- Conducting the screening
- Evaluation and report.

The quality of the screening results depends essentially on carefully planning the analysis

Tab. 10: Screening procedure of commercial waste

	Time
Data collection for time variation curve on quantity/firms/sector etc.	14 d
Preparing the screening	
Training the staff	1 d
Preparing the screening location	1 d
Organisation schema of the screening procedure	1 d
Consultation with the plant operator/ weighing manager	2 d
Introductory instructor	0,5 d
Development forms	1 d
Data processing	1 d
Screening conducted on each plant (at least one to two weeks)	6 - 12 d
Data input, evaluation and extrapolation with plausibility test (depending on the number of plants)	10 - 20 d
Report	10 d

This specifically applies for planning the screening location and the organization to be installed there. Each delivery should be screened separately. It is necessary that the delivery is spread loosely on the surface for the screening. After the screening (from all sides), which usually lasts 2 to 5 minutes, the heap is removed. The allotment of the transport vehicles should be carefully noted in order to assign the weights of the waste to their respective vehicles.

The screening surface should be large enough to minimize the waiting time for the delivery vehicles. Hectic rush should be avoided.

This can only be guaranteed if in addition to the screeners instructors who are able to realize more than one function are also employed:

- Allotment of space for unloading the waste to the delivery vehicles.
- Supervise that each container is emptied and that the weight of its contents are allotted to it.
- Organize that the screened waste is removed immediately.

The data of weights should be collected at the weighing machine and immediately added to the data from the screenings. At the same time or during the screening the apparent density of the materials and the type of vehicles should also be examined for suitability to the screening space. Specific apparent densities should be determined for this.

A wooden casing one meter high is constructed for this purpose. It has a rectangular outline and is open on one side. This side should be wider than the vehicle so that later on the containers can be emptied into this casing. After selected loads are emptied into the casing the waste heap is evened out carefully with a rake. One should avoid stepping on the waste.

After the waste has been evened out, the filling level is measured and the apparent volume is calculated. The apparent density is derived from the quotients apparent weight and apparent volume.

The evaluation is done either manually or with the help of adequate software depending on the extent of the single screenings.

A commercial waste screening makes a noticeable recess in the daily operation of a disposal plant. A broad range of information all involved (specific transporters) is therefore very important. This information should not be collected too much in advance but about a week before the screening.

8.5.3 Check lists for a commercial waste screening

The check list is exemplary and can be divided into four points:

- Allottment,
- Preparation,
- Conduction,
- Evaluation.

Allotment

- what data is available and what has to be obtained (influences time and costs for the contractor)
- extent of the weekly quantity of commercial waste (attach an annual time variation curve)
- number of relevant disposal plants
- differentiated according to waste groups
- definition of the work done by the person giving the order e.g. collecting data on the weight, instruction posts, clearing the screening location with wheel loaders, helping with information on the transporters
- defining the objectives of the analysis and describing the evaluation objectives, e.g. summarised according to sectors, calculating the recycling potential, characterizing mono batches, operational instructions, extrapolations on annual quantities and material groups

Preparation

- collecting statistical data
- defining screening time and extent
- drafting forms
- defining evaluation methods (manual/software)
- consulting plant operators
- consultation with the person in-charge of weighing
- Inspection of apparent density
- training the staff
- organistions schema for the screening location
- instructing the wheel loader driver and the person allotting the space
- information on the transporters

Conduction

- presence of the screening staff 15 minutes prior to opening the plant
- organising breaks
- daily input of data and adjusting with the weight data
- daily supervision on plausibility
- placement weather (independent of weather condition) (construction site trailer)

The evaluation is to be directed towards the target quantity. This requires that these targets are defined adequately in advance.

8.6 Chemical-physical composition

The chemical and physical composition of waste is analysed mainly in order to categorize it, e. g. high/low hazardous substance potential, which method of treatment can be used, etc. or establishing the attributes, such as nutrient contents, calorific value and similar. Representative samples and careful sampling beginnig from fresh samples up to their analyses are therefore very essential in order to get precise data out of the often very heterogeneous waste

Fundamentally, the diversity of the analyses is of course dependant on the aim of the tests. The following worked examples of laboratory analyses, therefore, represent only one option from the range of possibilities. For this reason, the analyses are distinguished into two groups:. It first of all aims at getting basic data on the suitability of the fractions after the screening and sorting analysis or of the whole analysed material for various methods of waste manageme or storage

Analyses which have to be carried out; and those which are optional in the testing range to gain more comprehensive basic data.

Useful analyses:

- bulk weight
- Water content
- Organic substance (incandescent heat loss)
- Gross calorific value.

The bulk weight of individual fractions, which are important for the size of containers, transport vehicles and the whole equipment, is best found already at the screening and sorting analysis at site. Sorting containers and respectable scales are available there.

Data on the water content is essential firstly to determine the special treatment (e.g. fermentation/composting), secondly to calculate the net calorific value (incinerator performance capacity). It is quite easy to get the necessary data (weighing before and after dehydration, calculating), as in most cases the waste samples have to be dried before further treatment in the laboratory can take place anyway.

The incandescent heat loss can be regarded as a way to measure the organic contents in the sample. The analysis (incineration of the sample in a muffle incinerator) is simple, and can be carried out quickly if the sample is already grinded. To get a rough idea of the content, it is possible to use samples from the shredder. However, a larger quantity has to be taken and the process must be repeated at least five times).The incandescent heat loss analysis provides information e.g. about the suitability of the sample for biological treatment (in conjunction with other parameters, such as the content of hazardous substance and plant nutrients, etc.) and about the suitability for storage in line with the technical law instructions on municipal waste. The data can be used for a rough calculation of the gross calorific value and of the carbon content (TOC) of the sample.

The gross calorific value analysis (H_o) is measured in calorimeters and is calculated using a dried, fine ground sample. As the analysis demands a lot of labour and equipment, it is only efficient in case of insufficient data. The results of the analyses are the basis for the exact calculation of the net calorific value (H_u), which is absolutely necessary for determining the dimensions of the thermal treatment units.

It should always be considered the necessity of any analysis, before it is carried out. Before taking samples the procedure should be arranged with the lab. Follow the national legal regulations for analyses.

8.6.1 An example for determining the burn residue of mixed house-hold waste

The dried and finely powdered sample used for the analysis should not weigh more than 10 g. For a sorting analysis of a mixed sample, the building development structure of a waste disposal area with 100 000 inhabitants is taken into account where 2 880 kg (moist) waste is collected, which with a water content of 40% would give 1 728 kg of dry substance. The sample to be analysed and which is supposed to represent the whole sample contains only 0,0058 ‰ of the original mass. To take a sample from the mixture is therefore inevitable.

In order to obtain reasonable data on the chemical and physical composition of the mixture all the individual substances screened and sorted out of the mixture are separately analysed. The weight of the original sample can be deduced from the weight of the individual parts.

From the collected mixture of household waste which and how much of the screening and sorting fractions are used as samples is shown in Tab. 11. Depending on the inspection targets individual fractions will have to be resorted and further divided.

Thus for e.g. for a later analysis of heavy metals it will be necessary to screen metal parts with a screening fraction 8-40mm and likewise for different kinds of paper and plastics.

Before preparing a sample it is advisable in the case of voluminous materials such as paper, plastics, native organic materials and residues to pre-crush the material to a particle size of < 60 mm which could be done with a cutting roller mill or something similar. This would help to crush all the fractions sorted in one day and would be a great advantage for mixing and dividing the samples (homogenity).

Tab. 11: Example of samples from mixed household waste for laboratory analyses (Weight of the whole sample 2 880 kg, moist)

Fraction	Quantity		Sample quantity		Sampling
	kg	%	kg	%	
0-8 mm	346	12,0	ca. 17	5	Flow proportional
8-40 mm	855	29,7	ca. 43	5	Flow proportional 1)
Paper	429	14,9	ca. 43	10	After pre-crushing to < 60 mm 1)
Plastics	135	4,7	ca. 7	5	After pre-crushing to < 60 mm 1)
Organic materials	533	18,5	ca. 53	10	After pre-crushing to < 60 mm
metals	109	3,8	ca. 5	5	After pre-sorting to magnetic/non-magnetic
Glass	199	6,9	ca. 10	5	flow proportional 1)
Inert substances	170	5,9	ca. 9	5	flow proportional 1)
Residue	104	3,6	ca. 20	20	After pre-crushing to < 60 mm
total	2 880 2)	100,0	207	-	

1) eventually resorting to be done before for different materials

2) ca. three days of sorting!

If the screening and sorting analysis is done on more than one day the daily samples should be listed according to the inspection target (e.g. to differentiate between individual collection tours or container size etc.) or to produce a mixed sample from the daily samples of each of the screening and sorting fractions. The method of preparing a statistically secure sample from a waste collection area and its analysis is described in detail in [11].

While sampling it should be noted that using wrong apparatus or sample holders will influence the laboratory analysis later on. Normally this is the case when analysing traces (heavy metals, organic pollutants etc.). Which materials are suitable to the equipment or container should be pre-defined.

The method described for mixed house-hold waste can also be applied for other kinds of waste such as useful materials (single kind and mixed), bio-waste, commercial waste similar to house-hold waste, residual waste from house-holds and all other waste that can be screened on sorting belt.

In the case of lumpy waste (e.g. bulky waste, waste from construction sites) it is advisable to deduce the property of the mixture from the material composition obtained by optical classing and from the secondary statistical values (e.g. heating value for wood, plastics).

It only makes sense to crush a huge charge on a large scale and screen it (inspection of the screening fractions) or separate out single pieces for a closer analysis if there are special questions.

8.6.2 Sample preparation

Following is a description of how a single sample selected from the screening and sorting fraction, handled according to the measures described in chapter 4.3.2 Material composition, is prepared in the laboratory (flow chart Fig. 3.9).

If possible the sample mixing and singling should take place on location at the sorting place so that only a max. of 20 l contents or a mass of 10 kg will have to be processed.

The samples will have to be winnowed for homogeneity and particle size at the time they are received in the laboratory so that a starting mixture can be made in the case of homogenous samples and divided into the required portions for an analysis of the fresh material (e.g. pH-value, self-heating etc.). Generally 10 l i.e. 10 kg of the material are dried at the most.

With particles > 10 mm, it may be necessary to conduct a screening or reduce the size before an analysis on the fresh material is done. The size reduction is preferably done in a cross-beater mill having a 10 mm strainer screen and should function even with very moist materials. A screening is only necessary if the oversized particles produce little or no assessable amount of analytical results. (e.g. for self heating experiments).

Normally a drying oven is used spacious enough even for voluminous samples. The temperature chosen (between 40 and 105ûC) depends on what the next analysis steps are going to be (e.g. for organic pollutants etc.). Smaller amounts of samples can also be freeze-dried.

The drying is followed by a further mixing and dividing of the sample in which materials > 10 mm are reduced in size in advance with a shredder (strainer screen 10 mm) or any other adequate cutter. It would be of advantage at this stage to carry out a further sorting out for example metal parts, glass etc. to prevent adulteration of analytical results or to separate material groups that could not be sorted out in wet condition. If more sample material should be required at a later period, dried substances < 10 mm should be taken as a first retain sample which can be further treated if necessary. The remaining samples that are of no further use are discarded.

As a second step to further reduce the size of the sample particles, 200-500 g (depending on the apparent density) of the dried and when necessary pre-shredded samples is ground in a centrifugal mill having a mesh bottom, a ball mill, a disc mill or some other mill till it is reduced to the necessary grain size needed for the analysis (usually < 250 m). Care should be taken that the wear debris does not influence the subsequent analysis. Therefore grinders made of Chromium-Nickel alloys cannot be used when analysing heavy metals as in AbfKlŠrV, or sintered corundum grinding beakers (Al_2O_3), for detecting Aluminium. The high temperatures that are sometimes caused during grinding could also be significant.

One should reckon with a lot of dust while grinding dry materials. If closed grinding beakers are used (e.g. ball mills) this plays only a subsidiary role as dust develops only while filling in or trans-filling the sample materials or while sieving on to a test screen (analysis size) If a blade-mill or a centrifugal mill is used, wearing a fine-dust mask should be compulsory for the lab workers.

In the case of elastic or viscous materials (plastics or textiles) it may be necessary to embrittle the material by cooling with liquid nitrogen before it is ground. In this method which was developed at the University of Stuttgart the pre-cut sample is put into a Dewar flask filled with liquid nitrogen. By continuously adding liquid nitrogen out of the suction container directly into the feed funnel of the centrifugal mill having a strainer screen, successive small amounts of sample (about 20 ml) swimming in liquid nitrogen, can be proportioned.

The expenses for this method (time and liquid Nitrogen usage) are quite high and therefore justified only for special cases. Safety precautions such as the wearing of safety goggles, gloves and long lab coats should be implicitly followed to prevent eye injuries and frostbites.

The second (fine) shredding step is followed by a further sample mixing and proportioning, during which it might be necessary to examine the grinding fineness of the sample on a test screen and grind possible residues once more. Depending on the mill charge a 50-200 g retain sample and analysis samples (number and quantity as needed) are removed and the remaining sample is discarded.

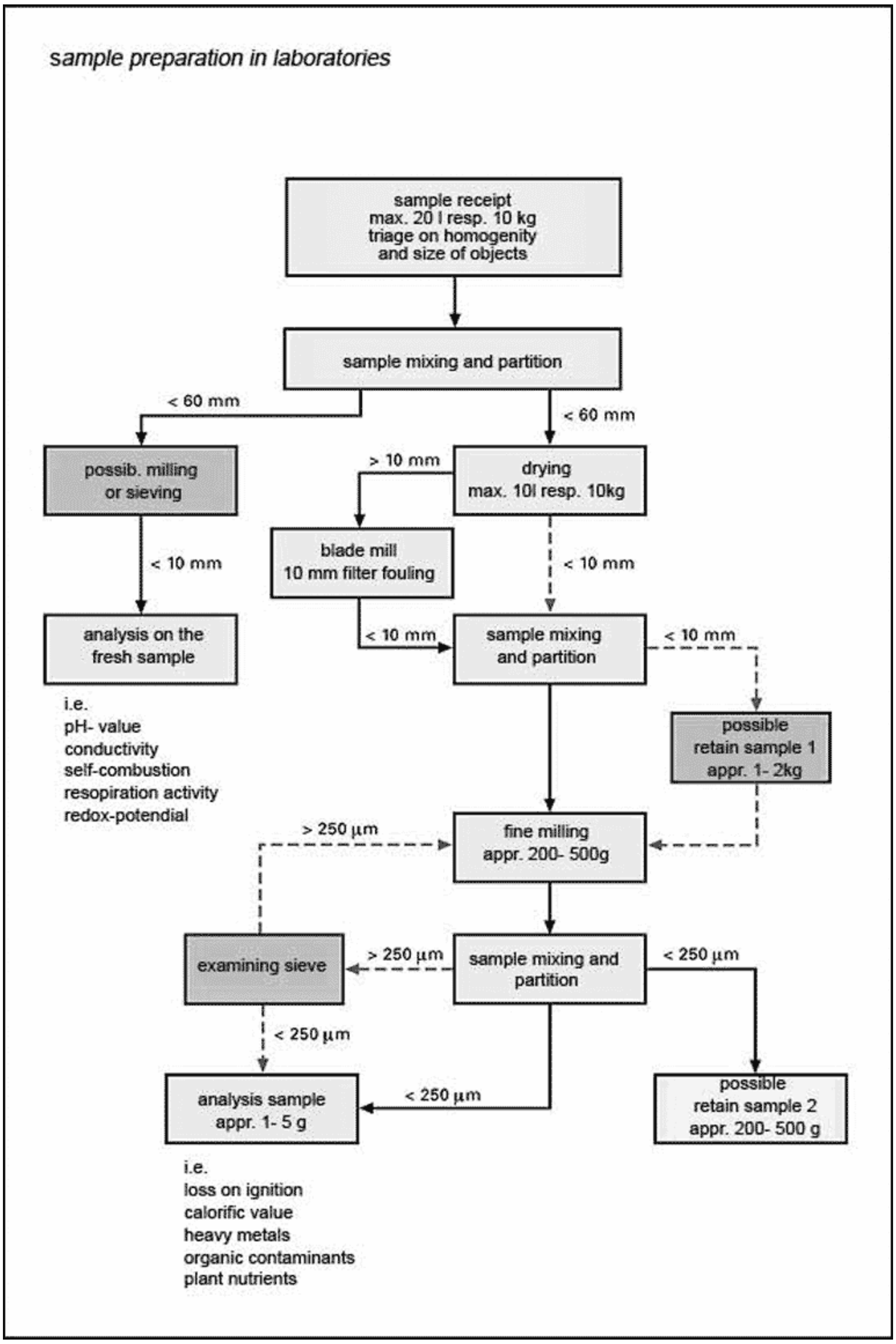

Fig. 9: Sample preparation in the laboratory (sample < 60 mm)

8.6.3 Analyses

The extent of the analyses basically depends on what target of the studies are. The analyses already conducted in the laboratories and described in the following are therefore only suggestions for a possible procedure which above all are meant for compiling a data basis to detect the adequacy of the fractions obtained by screening and sorting analysis or data on all the material studied to determine different methods of treating waste and storing waste.

One should here differentiate between those analyses which have to be conducted in any case and those that are optional and could be included in order to have a more extensive data basis.

Definitely meaningful analyses

The analyses in this category are:

- Volumetric weight,
- Water content,
- Organic substance (burn loss) and
- Fuel value (H_o).
- Volumetric weight

The specific weight of the individual fractions which is an important quantity for dimensioning containers, transport vehicles and all the components of a treatment plant, can be best be determined on the spot by the screening and sorting analysis. Sorting containers and appropriate weighing machines are available for this (ref. chapter 3.3 Container identification data).

Determining the water content is necessary for narrowing down to a specific waste-treatment method (e.g. fermentation/composting) and also to calculate the fuel value (H_u) (efficiency of an incinerator). A minimum effort is needed for determining this (weighing after drying, calculation) since most waste samples have to be dried in any case before further processing them in the laboratory.

The burn loss can be used as quantum for the organic substance in a sample. It can be easily and quickly analysed (combustion of the sample in a muffle furnace) if the sample is already finely ground. In order to obtain a first clue to the composition of the sample, material that has already been ground in a blade mill can be used.(with added net weight and at least five reruns).

The burn loss analysis is needed for e. g. to determine the suitability of the sample for biological treatment (together with other parameters such as contents of pollutants and nutrients) and to test whether it can be stored according to the TA of community waste. The value got from the analysis can be used to estimate the fuel value (H_o) and the content of Carbon (TOC) in the sample.

The analysis of the fuel value (H_o) is done in a calorimeter with the dry finely powdered sample. The man power needed is quite high and a lot of apparatus too is required so it is only interesting to determine this value for particular samples for which no definite values are known. The value analysed is the basis for exactly calculating the heating value (H_u), which is indispensable for dimensioning thermic treatment plants.

Optional analyses

There is generally no doubt that it is possible to look for all analysable materials in wastes. However one should reasonably narrow down the possibilities for screen and sorting analysis in order to obtain a data basis on the suitability of various materials for the different waste treatment methods and their landfilling.

A first rough classification after the analysis can be made as follows:

- Substances that offer a value (relevant mainly for producing compost, but also for the recovery of valuable substances),
- Pollutant potential (heavy metals, organic pollutants in general, also salt content and pH-value for biological treatment suitability) and
- Classification criteria for the individual treatment methods and storage (catalogue as attachment B of the TA community waste)

Depending on the study targets, the extent and number of analyses can be defined. Choices of analysing methods for the three main groups mentioned are described in the following.

Interesting are those substances that have value for an intended biological waste treatment leading to a product particularly plant nutrients such as Nitrogen (N), Phosphorus (P), Potassium (K) and Calcium (Ca). All decomposable and fermentable waste, whose suitability (in connection with its pollutant potential) for biological treatment is to be tested, can be considered for analysis. The easily soluble contents as well as the complete contents can be determined.

Similarly the gas potential of organic materials could also be of interest for their suitability for biogas plants (methane generation). This data can be collected from a fermentation test followed by an analysis of the gas quantity and gas composition (gas chromatograph).

To determine the pollutant potential of waste streams they are normally analysed for heavy metals (lead, cadmium, chromium, copper, nickel, mercury, and zinc as in AbfKlŠrV) and/or their content of organic pollutants (PCDD/F, PCB, PAK). These analyses are particularly interesting if an evaluation of the tested fraction or the mixture is aimed at. This can be very expensive (especially organic pollutants) and can therefore be done for special cases only. The special rules for sampling and processing should be emphasized here.

A low pH-value can be considered as one of the harmful potentials for biological processes (only composting), the salt content is another (composting and fermentation). Both analyses are conducted on the fresh sample in eluate with electrodes by which the electrical conductivity is measured to deduce the salt content. This method is quick and cheap.

Whether a material is always suitable for composting can be determined by a self-heating test on the moist sample in a Dewar flask. It would be wise to add substances that will accelerate the decomposition.

Attachment B should be referred to for concerning the classification criteria for landfilling as in TA municipal waste. Accordingly the following points should be determined:

- The solidity of the waste materials,
- The proportion of organic substances in its dry state
- The extractible lipophile substances and
- And a whole row of eluate criteria (particularly the content of heavy metal and organic pollutants as well as pH-value and conductivity, a total of 17 analyses).

All the analyses mentioned there have to be carried out in order to classify the waste materials according to landfilling categories and to furnish proof of their storage suitability.

In a recapitulating manner it could be recorded once more that: Each of the analyses is only significant as the sampling and processing will allow it. Especially while analysing trace elements (sometimes in the ppb-area) a representative sample selection should be made and careful handling during sampling and in the laboratory following appropriate rules is important e.g. even a minimal carrying on of the test samples in various apparatus or containers can lead to strong deviations in the analysis data.

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