



WEEELABEX

Documentation to measure depollution



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Introduction

The purpose of this document is to provide the tools to assess the depollution performance of processes taking place at treatment companies.

The WEEELABEX normative requirements on treatment require that de-pollution performances must be monitored (WEEELABEX normative document on Treatment, 5.4).

Monitoring of de-pollution performance shall be determined by one or several of the three following methodologies:

- Method 1: quantification of the outgoing stream and comparison with a target value or assessment of progress,
- Method 2: establishment of a mass balance between incoming and outgoing streams, and
- Method 3: analysis of representative samples of relevant fractions from treatment of de-polluted WEEE.

This document describes the related procedures and methods that have to be followed in order to measure the pollution efficiency of the treatment facility.

Setting up limit values is the responsibility of the WEEE Forum. WEEE Forum gathers the data provided by each country or relevant playing field area and determines the limit values.

The following table gives the measures that shall be done for each flow to properly assess the efficiency of depollution.

Flow	Method 1 : Benchmarks		Method 2 : Mass balance		Method 3 : Output fractions analyses		
	Component	Protocol	Substance	Protocol	Fraction	Substance	Protocol
LHA	Capacitors	Weighing protocol and benchmark protocol	Not applicable	Not applicable	Shredder light fraction	PCB	Sampling and analysis protocol for the shredder light fraction
	Printed circuit boards					Cadmium Copper	
SHA	Capacitors	Weighing protocol and benchmark protocol	Not applicable	Not applicable	Shredder light fraction	PCB	Sampling and analysis protocol for the shredder light fraction
	Batteries					Cadmium Copper	
	Printed circuit boards				Plastics	Bromine Restricted BFR	Sampling and analysis protocol for plastics
CRT screens	Capacitors	Weighing protocol and benchmark protocol	Not applicable	Not applicable	Ferrous metals / Mix fraction / Deflection coil / Electron gun	CRT glass	Sampling and analysis protocol for glass in fractions from CRT appliances
	Printed circuit boards						
					Panel or mixed glass	Sulphur	Sampling and analysis protocol for CRT glass after the removal of fluorescent coatings
					Panel glass	PbO	Sampling and analysis protocol for the panel glass fractions from CRT display appliances
					Plastics	Bromine in plastic pieces Restricted BFR	Sampling and analysis protocol for plastics
FPD screens	Capacitors	Weighing protocol and benchmark protocol	Mercury recovered after shredding	Mercury mass balance protocol for mechanical treatment of Flat Panel Displays (FPDs)	Shredded mixed fraction	Mercury	Sampling and analysis protocol for a "Shredded mix fraction" of FPD
					Plastics	Bromine in plastic pieces Restricted BFR	Sampling and analysis protocol for plastics

Flow	Method 1 : Benchmarks		Method 2 : Mass balance		Method 3 : Output fractions analyses		
	Component	Protocol	Substance	Protocol	Fraction	Substance	Protocol
C&F	Capacitors	Weighing protocol and benchmark protocol	VFC and VHC recovered in step 1 VFC and VHC recovered in step 2	End of life requirements for household appliances containing volatile fluorocarbons or volatile hydrocarbons	Oil from compressors	VFC	EN50574:2012 and TS50574
					PU foam	VFC	
					Metallic fractions	PU foam	
					Plastic fractions	PU foam	

Table 1

1. Method 1: Benchmarks

1.1. Introduction

1.1.1. *Scope of the benchmarks*

Several substances of concern and components to be removed are subject to the benchmarks:

- **Batteries**
- **Capacitors**
- **Printed circuit boards**

1.1.2. *Normative references and standards*

Standards specific to electrical and electronic equipment and waste

IEC/PAS 62596: Electrotechnical products – Determination of restricted substances – Sampling procedures – Guidelines

WEEELABEX Standard on Treatment – Annex A: Depollution guidelines

WEEELABEX Standard on Treatment – Annex B: Depollution monitoring

WEEELABEX Standard on Treatment – Annex C: Requirements concerning batches

Sampling norms for the measurement of waste composition

EN 14899: Characterization of waste – Sampling of waste materials – Framework for the preparation and application of a sampling plan.

CEN/TR 15310-1: *Guidance on selection and application of criteria for sampling under various conditions*

CEN/TR 15310-5: *Guidance on the process of defining the sampling plan*

1.1.3. *Terms and definitions*

Incoming flow: Flow of WEEE appliances that is processed in a treatment plant (also called treatment flow). 6 flows are basically distinguished: Large Household appliances (LHA), Cooling & Freezing appliances (C&F), Flat panel displays (FDPs), Screens (CRTs), Small Household appliances (SHA) and lamps.

WEEE sampling: measurement of the weight percentage of each category or each kind of product that constitute an incoming flow.

Category: Category of electrical and electronic products defined in annex I of WEEE directive 2002/96/CE.

Batch: manual or mechanical processing of a definite and well-defined amount of WEEE or fractions thereof to determine the yields and compositions of the resulting output fractions and de-pollution performance (WEEELABEX Standard on Treatment).

Components: Components that have to be removed from WEEE according to annex II of directive 2002/96/CE. Those in scope of benchmarks are: capacitors, batteries and printed circuit boards.

Limit value: Minimum quantity of polluting components that have to be removed by treatment facilities per ton of incoming flow. This value is the end result of benchmarks work.

1.1.4. Generalities on benchmarks

Benchmarks consist in comparing data reflecting the day-to-day activity to objectives fixed by the body in charge of the evaluation. The day-to-day activity data may be batches data but whenever it is possible annual data.

They shall include:

- Quantities treated (input)
- Pollutants removed (output)

Fixing the objectives of the pollutants to be removed can be done for WEEE, by several means. Those means to assess the pollutant input are described in *Annex 1: Assessment of pollutants in input appliance*.

Different approaches for pollutant input

4 approaches for benchmarks:

1. Enquiries among producers about pollutants content in appliances;
2. Investigation through batches on actual treatment results;
3. Statistical input analyses of incoming flow;
4. Statistical input analyses detailed by categories and/or type of appliance;

The focus will be made on the last three methods: batches, input analyses of incoming flow and input analyses details by categories or types of appliances.

Note: the “batches” method described in *Annex 1: Assessment of pollutants in input appliance*. Annex 1 Approach 2 may be difficult to set up for historical flows but could be kept for the future.

Data from day-to-day operations

Once the objectives to be reached are fixed, the components removed during WEEE treatment have to be accounted in the same way in order to be comparable to each other.

Required tools:

- Weighing protocol
- Calculation protocol

1.2. Weighing protocol

We distinguish in this part:

- Weighing protocol for input material and for components removed during a batch;
- Weighing protocol for the components removed during an assessment of pollutants in input WEEE.

1.2.1. Weighing protocol for input material and components removed during a batch

Weighing of input material and components removed during the batch must follow the requirements described in *WEEELABEX Standard on Treatment – Annex C: Requirements concerning batches*.

Input material may include sorting mistakes (ex: Screens in SHA Flow). When it is possible, the sorting mistakes should be taken out of the input material before running the batch, so that only products that belong to the normal flow remain as input material.

1.2.2. Weighing protocol for removed components

Only components removed from the processed incoming appliances must be accounted (and not be added up to components removed from other treatment flows or waste). Components must be weighed separately per type (capacitors, batteries, printed circuit boards).

The weighing equipment used should have sufficient accuracy and must be regularly checked. The weight of the recipient in which the components are gathered together for weighing shall be deducted to the gross weight in order to obtain the net weight of components (net weight = gross weight – tare weight).

1.2.3. Details on the components before weighing

Capacitors

In order to be able to have comparable results, it is necessary to make sure that:

- only the kinds of capacitors in scope (see *Annex 3: Details on components in scope*) removed from the incoming flow will be weighed
- all removed capacitors will be cleared of cable and printed circuit boards' pieces before weighing
- capacitors will be separated from any other kind of removed components (ex: from batteries; an easy way to distinguish capacitors from batteries is to look if the component is marked with "µF" which is the capacity unit symbol, only present on capacitors)

Batteries

In order to be able to have comparable results, it is necessary to make sure that:

- all removed batteries will be cleared of printed circuit boards' and cable pieces before weighing
- batteries will be weighed separately from any other kind of removed components (ex: capacitors) from input appliance

Printed circuit boards

In order to be able to have comparable results, it is necessary to make sure that:

- all printed circuit boards removed from the incoming flow will be weighed (see *Annex 3: Details on components in scope*)
- all removed batteries and capacitors in scope will be cleared out of printed circuit boards' pieces before weighing

Note1: printed circuit boards can be removed at several steps in the treatment process. The quantity removed at each step must be weighed and registered for accounting.

Note2: In addition, samples of output fractions (fractions: capacitors, batteries, printed circuit boards) could be taken out once a year to determine what is the average quantity of out of scope components in the removed fractions (ex: too small capacitors, pieces of cables, etc.). Based on these measurements, a correction factor would be applied in the batches results to determine the real quantity of removed components in scope.

For instance:

- the quantity of capacitors removed during the batch is 240 kg
- the analysis of a sample of 10 kg shows that 1 kg (= 10% of 10 kg) are out of scope capacitors (volume < 12,27 cm³)
- after correction we obtain that the removed quantity of capacitors in scope is 90% of 240 kg = 216 kg; we replace it in the batches results

1.3. Benchmarks protocol and limit values

1.3.1. Assessment of the pollutants present in appliances

4 approaches exist to determine the pollutants present in appliances:

1. Enquiries among producers about pollutants content in appliances;
2. Investigation through batches on actual treatment results;
3. Statistical input analyses of incoming flow;
4. Statistical input analyses detailed by categories and/or type of appliance;

The focus will be made on the methods 2, 3 and 4: batches, input analyses of incoming flow and input analyses details by categories or types of appliances.

Those methods are described in *Annex 1: Assessment of pollutants in input appliance* and shall be used to collect data by representative entities allowed to assess the pollutants present in appliances and provide limit values.

1.3.2. Remarks on the calculated target values to be compared with day to day results

▪ Lower tolerance limit based on the variability of the data

The target values calculated in approaches 2, 3 and 4 are average values based on measurements.

Nevertheless, we can set as acceptable lower limit: the lower bound value of confidence interval around the calculated average value (this lower limit value that takes into account the uncertainty margin of the calculated average, based on the variability of the measurements - see Annex 1, chapters 1.2.2, 2.2.3 and 3.2.4)

Target value: mean value

Lower limit: mean value – ½ width of confidence interval

▪ Tolerance factor taking into account actual technical limits of treatment processes

Approaches 3 and 4 give theoretically 100% of the quantity of components that are present in appliances.

Approach 2 gives less than 100% of the quantity of components in appliances:

- treatment processes may not be able to remove all the components due to technical limits
- the complete data concerning certain kinds of components (ex: printed circuit boards) may not be available through batches (printed circuit boards are often not removed before shredding and are weighed together with other NF-fractions after shredding)

That's why an additional tolerance factor could be applied to the objective value calculated through approaches 3 and 4.

1.3.3. Management of limit values

Each country or relevant level playing field area should be subject to appropriate limit values adapted to the composition of the flows treated.

Each country or relevant level playing field area is free to use one or several of the approaches described in *Annex 1* to assess the pollutants in the input.

Setting up limit values is the responsibility of the WEEE Forum. WEEE Forum gathers the data provided by each country or relevant playing field area and determines the limit values according to the composition of the different flows treated. Limit values may differ from one country or relevant playing field area to another if the input flow is different.

We present below a draft proposition of limit values table for WEEE Forum:

WEEELABEX - Limit values for benchmarks

in kg/ton

RELEVANT PLAYING FIELD AREAS	LHA		SHA			CRT screens		FPD screens	C&F
	Capacitors	Printed circuit boards	Capacitors	Batteries	Printed circuit boards	Capacitors	Printed circuit boards	Capacitors	Capacitors
Area 1									
Area 2									
Area 3									
Area 4									
Area 5									

Table 2 Example of a WEEE Forum limit value table

WEEELABEX - Temporary limit values for benchmarks

in kg/ton

RELEVANT PLAYING FIELD AREAS	LHA		SHA			CRT screens		FPD screens	C&F
	Capacitors	Printed circuit boards	Capacitors	Batteries	Printed circuit boards	Capacitors	Printed circuit boards	Capacitors	Capacitors
Europe	1,3 kg/ton	1,0 kg/ton	0,9 kg/ton	1,8 kg/ton	19 kg/ton	1,0 kg/ton	56 kg/ton	1,0 kg/ton	0,08 kg/ton
France	1,4 kg/ton	1,6 kg/ton	0,9 kg/ton	4,9 kg/ton	52 kg/ton	1,0 kg/ton	56 kg/ton	1,0 kg/ton	0,08 kg/ton
Italy	1,0 kg/ton	0,7 kg/ton	0,9 kg/ton	1,8 kg/ton	19 kg/ton	1,0 kg/ton	56 kg/ton	1,0 kg/ton	0,08 kg/ton

Table 3 Table of WEEE Forum temporary limit values for benchmarks

These values are first interim limit values based on statistical analyses of measurements data from Western European countries. As soon as data from other relevant playing field areas will be available, the limit values for other playing field areas will be calculated.

See the WEEELABEX Statement no. 2016_006 for the detailed information on depollution target values calculation method.

2. Method 2: Mass balance of Temperature Exchange Equipment

2.1. Introduction

The WEEELABEX normative requirements on treatment stipulate that de-pollution performance shall be monitored (WEEELABEX normative document on Treatment, 5.4).

Monitoring of de-pollution performance shall be determined by one or several of the three following methodologies:

- quantification of the output streams and comparison with a target value or assessment of progress,
- establishment of a mass balance between incoming and output streams
- analysis of representative samples of relevant fractions from treatment of depolluted WEEE"

The present part describes the protocol which has to be used together with the EN50574:2012 to implement the second methodology for the treatment of Temperature Exchange Equipment.

2.2. Parameters

For the Temperature Exchange Equipment the following parameters shall applied to evaluate the performance of the treatment together with the requirements of the EN50574:2012.

Targets and characteristic numbers:

- Target value for the recovery of VFCs: $tv_{VFC} = 0,9 \times M_{VFC} / PU_{VFC}$ (expressed as g VFC per kg PU_{VFC});
- Target value for the recovery of VHCs: $tv_{VHC} = 0,9 \times M_{VHC} / PU_{VHC}$ (expressed as g VHC per kg PU_{VHC});
- VFC concentration in VFC PU: $f_{VFC} = 8,5\%$;
- VHC concentration in VHC PU: $f_{VHC} = 3,8\%$.
- The values for $w_{i,VFC}$ and $w_{i,VHC}$ for the Northern European countries are:
 - $w_{Ni,VFC}$: cat 1: 3,66 kg; cat 2: 4,88 kg; cat 3: 6,10 kg;
 - $w_{Ni,VHC}$: cat 1: 4,36 kg; cat 2: 5,81 kg; cat 3: 7,26 kg;
- The values for $w_{i,VFC}$ and $w_{i,VHC}$ for the Mid European countries are:
 - $w_{Mi,VFC}$: cat 1: 3,14 kg; cat 2: 4,18 kg; cat 3: 5,23 kg;
 - $w_{Mi,VHC}$: cat 1: 4,36 kg; cat 2: 5,81 kg; cat 3: 7,26 kg;
- The values for $w_{i,VFC}$ and $w_{i,VHC}$ for the Southern and Eastern European countries are:
 - $w_{SEi,VFC}$: cat 1: 2,45 kg; cat 2: 3,26 kg; cat 3: 4,08 kg;
 - $w_{SEi,VHC}$: cat 1: 4,36 kg; cat 2: 5,81 kg; cat 3: 7,26 kg;
- In case the Recovery of VFC and VHC in a performance test is greater than 110% in respect of the potentially recoverable amount, the performance test shall be evaluated as invalid (for example in case that $g_{in,VFC} > 110\% \times M_{VFC} / PU_{VFC}$ the test shall be evaluated as invalid). This can only be otherwise where such a result has an explicable reason evaluated and confirmed by the C&F Specialist Lead Auditor.

Monitoring system:

- In day-to-day business the mass of refrigerant recovered shall be not lower than 90% of the expected amount (VFC expected: 126 g of refrigerant per intact refrigerating system. VHC expected: 54 g of refrigerant per intact refrigerating system).
- In day-to-day business the mass of oil recovered shall be not lower than 90% of the expected amount (240 g per compressor).

- In day-to-day business the mass of blowing agent recovered (or destroyed) per kilogram PU_{VFC} and PU_{VHC} shall be not lower than 90% of the expected amount.

Northern European countries are:

- Denmark;
- Estonia;
- Finland;
- Iceland;
- Ireland;
- Latvia;
- Lithuania;
- Norway;
- Sweden;
- United Kingdom.

Mid European countries are:

- Austria;
- Belgium;
- France;
- Germany;
- Luxembourg;
- Netherlands;
- Switzerland.

Southern and Eastern European Countries are:

- Bulgaria;
- Croatia;
- Cyprus;
- Czech Republic;
- Former Yugoslav Republic of Macedonia;
- Greece;
- Hungary;
- Italy;
- Malta;
- Poland;
- Portugal;
- Romania;
- Slovakia;
- Slovenia;
- Spain;
- Turkey;

Note 1: The composition of macro geographical (continental) regions, geographical sub-regions, and selected economic and other groupings is taken by the United Nation statistic division.

Note 2: The results of the Step 1, Step 2 and Step 3 C&F performance test shall be reviewed and evaluated by the C&F Specialist Lead Auditor to verify that there were no malfunctions or deviations that could devalue the results. It is recommended to the C&F Specialist Lead Auditors to calculate the theoretical approximate differences/deviations that could occur during the performance tests and take this calculation into the consideration when evaluating the results. Those differences/deviations can vary case by case depending on different scales, technology, processes, etc.

3. Method 2: Mass balance Flat Panel Displays

3.1. Introduction

The WEEELABEX normative requirements on treatment stipulate that de-pollution performance shall be monitored (WEEELABEX normative document on Treatment, 5.4).

Monitoring of de-pollution performance shall be determined by one or several of the three following methodologies:

- quantification of the output streams and comparison with a target value or assessment of progress,
- establishment of a mass balance between incoming and output streams
- analysis of representative samples of relevant fractions from treatment of depolluted WEEE"

The present part describes the protocol which has to be used to implement the second methodology for the treatment of Flat Panel Displays (FPDs) containing mercury backlights.

3.1.1. Scope

This document concerns manual treatment and mechanical treatment of FPDs.

Manual treatment of FPDs is a process for which mercury backlights are generally extracted manually in order to save their integrity to avoid mercury pollution. However, during this process, some mercury backlights may be broken, enabling the release of mercury.

The present document covers treatment of FPDs from the first dismantling step until the delivery of de-polluted (mercury free) output fractions (pure or mixed materials) intended to be recycled.

Mechanical treatment of FPDs (e.g. shredding process) is a process which intentionally breaks the mercury backlights and intends to depollute the mercury that has been mixed into the materials.

The present document covers treatment of FPDs from their feeding into the installation until the delivery of de-polluted (mercury free) output fractions (pure or mixed materials) intended to be recycled.

This document includes the following items:

- **test procedure** that describes the different steps to follow

For manual treatment:

- *determination and calculation of the mercury de-pollution efficiency rates. This is calculated as a percentage of intact lamps and lamps broken by the operator during the treatment process.*

For mechanical treatment:

- **quantification of mercury in the incoming stream.** This is the total mercury quantity initially present before treatment in all the FPDs part of the reference batch
- **measurement of mercury quantity in the output streams** which is the sum of the mercury content in all the types of output fractions (solid, liquid and gas).
- **mass balance calculation** as a comparison between the quantification of mercury in the incoming stream and the measurement of mercury quantity in the output streams.

3.1.2. References

"Sampling and analysis protocols", in chapter 4.3 of this document

WEEELABEX standard on treatment

EN 1483: Water quality, Determination of mercury.

3.1.3. Terms and definitions

Backlight: part of the flat panel module found in some flat panel displays technologies that illuminates the panel to make the image visible.

Cold Cathode Fluorescent Lamp (CCFL): type of mercury lamps used for LCDs backlighting.

Cold Vapour Atomic Absorption Spectrometry (CVAAS): a technique used in the measurement of trace amounts of volatile heavy metals such as mercury.

Flat Panel Display (FPD): thin screen equipment, larger than 100 square centimetres (cm²), using technologies that produces and displays an image without the use of cathode ray tubes. It mainly includes TVs, computer monitors and laptops.

Liquid Crystal Display (LCD): type of FPD that uses the light modulating properties of liquid crystals. As liquid crystals do not emit light directly, this type of device is usually backlit. LCDs make up the majority (up to 75%) of the FPD waste stream

Light Emitting Diode (LED): semiconductor light source used for backlighting in new generations of LCDs screens

Pyrolysis: decomposition of a substance at high temperature in the absence of oxygen.

Reference batch: all the FPDs selected for the mercury mass balance test.

Sample: portion of material selected from a larger quantity of material (ISO 11074:2005)

3.2. Test procedure *for mechanical treatment*

This procedure consists of the following steps:

3.2.1. Preparation of the reference batch

In order to facilitate and to make more reliable the quantification of the incoming mercury, a reference batch shall be prepared in order to exclusively contain the following FPDs (see Annex 7, paragraph 2.1):

17" and 19" LCD monitors which contain mercury backlights (CCFLs)

Note: Other 17" or 19" LCD monitors which do not contain mercury backlights (for instance with LED backlights) shall not be included. Where there is uncertainty, it shall be excluded from the reference batch.

Other requirements:

- in case of mechanical treatment, the quantity of monitors shall enable a 4 hours running at average treatment capacity and a minimum of 4 tons;
- all monitors shall be in good condition (screen not broken), complete, with or without their stand;
- all monitors storage containers used for the reference batch shall be weighed by equipment with proper calibration evidences;
- in case of mechanical treatment, the monitors shall be counted in order to determine the total number of units in the reference batch;
- storage and handling:

- they shall be stored under weatherproof covering or in enclosed weatherproof containers to prevent mercury contaminated rainwater being generated;
- monitors shall be carefully stored and handled to prevent breakage of the fragile internal mercury backlights. Where stacking containers on top of each other, precautions shall be taken to prevent damage to the displays in containers underneath.

3.2.2. Preparation of the processing units, areas and associated equipment

All the equipment, processing machinery, tanks, storage containers or areas, working areas, involved in the treatment process, shall be emptied and cleaned as much as possible to ensure no residual traces from a previous campaign.

In case of mechanical treatment, if a liquid is used and if it can absorb mercury during treatment, then a sample of this liquid shall be collected before starting the treatment of the reference batch in order to be able to assess the initial mercury content.

In case of mechanical treatment and in the case of the presence of a liquid/gaseous piping system, the operator shall ensure there is no leak that may impact the result.

For sampling and analysis protocol, see paragraph 3.5.2 In liquid streams.

Moreover the installation shall include a measurement equipment to quantify the mercury reclaimed by the filtering unit. This equipment is also needed during operation to be able to control the good efficiency of this filtering unit.

It should consist of:

- sensors to monitor the mercury contents before and after the filter and the air flow rate;
- a computer in order to calculate the collected mercury quantity.

For analysis protocol, see paragraph 3.5.3 In gas streams.

3.2.3. Treatment of the reference batch

The total mass of input material should be processed as a batch: if the batch is not processed during the same day, adequate control measures shall be enforced to ensure no mass is removed or added to the reference batch at any points on the process circuit during short or long period breaks.

For mechanical treatment:

At the end of the reference batch treatment,

- all the output fractions shall be weighed by equipment with proper calibration evidences;
- for wet process, the weight of the liquid used in the process for the batch treatment shall be assessed.

3.2.4. Validation of the reference batch treatment in case of mechanical treatment

The treatment of the reference batch shall be validated only if:

**Losses (total input material – total output fractions)
or gains (total output fractions – total input material)
stay below 5% of the total input material**

3.2.5. Measurement of reclaimed mercury

See paragraph 2.4

3.2.6. Quantification of incoming mercury for mechanical treatment

See paragraph 3.44

3.2.7. Measurement of mercury quantity in output streams for mechanical treatment

See paragraph 3.55.

3.2.8. Mass balance calculation

See paragraph 06.

3.3. Determination of percentage of lamps broken by the operator during the treatment process compared to intact lamps

This paragraph aims to define how to calculate a percentage of intact lamps and lamps broken by the operator during the treatment process.

3.3.1. Description of the process

During the reference batch treatment:

- *the mercury backlights broken during extraction must be cautiously counted.*
- *all monitors that already have broken mercury backlights before the extraction operation must be rejected from the reference batch.*

This reference batch treatment can be combined with the regular batch test.

3.3.2. Description of the parameters

- *Total mass of intact lamps* [kg] *I*
- *Total mass of lamps broken by the treatment operator* [kg] *B*

3.3.3. Formulas

$$\text{Hg de-pollution efficiency (DE)} = \frac{I}{I + B} \times 100$$

3.3.4. Compliance criteria

During the manual treatment process the treatment operator shall ensure that 95% of the intact backlight lamps are not broken.

3.4. Quantification of incoming mercury for mechanical treatment

This paragraph aims to define how to evaluate the total mercury quantity present in the reference batch before treatment.

3.4.1. Mercury quantity per CCFL

Hg Q / CCFL: Mercury Quantity per CCFL coming from 17" or 19" LCD monitors

$$\begin{aligned} \text{Hg Q / CCFL} &= 2,10 \text{ mg } \pm 0,7\% \\ (\text{i.e. Hg Q / CCFL min} &= 2,087 \text{ and Hg Q / CCFL max} = 2,116 \text{ mg}) \\ &\text{See Annex 7, paragraph 2.3.} \end{aligned}$$

Because the waste FPDs stream is subject to changes with years, such a measurement campaign should be conducted regularly in order to update the above reference values.

3.4.2. Number of CCFL per LCD monitor

Most 17" and 19" LCD monitors use 4 CCFLs for backlighting.
A small percentage, p%, of these monitors can use only 2 CCFLs per unit.

N CCFL / unit: number of CCFL per 17" and 19" LCD monitor

$$\text{N CCFL / unit} = 4 \times (1 - p\%) + 2 \times p\% = 4 - 2 \times p\%$$

With $p\% = 5/69$ (see Annex 7, paragraph 2.2), we obtain:

$$\text{N CCFL / unit} = 3,855$$

Because the waste FPDs stream is subject to changes with years, such a measurement campaign should be conducted regularly in order to update the above reference values.

3.4.3. Number of LCD monitors in the reference batch

N Unit / RB: Number of Unit (17" or 19" LCD monitors) in the Reference Batch

N Unit / RB has to be determined
during the preparation of the reference batch before treatment (see paragraph 3.2.1)

3.4.4. Incoming mercury quantity

In Hg Q: Total Incoming Mercury Quantity in the reference batch

$$\text{In Hg Q} = (\text{N Unit / RB}) \times (\text{N CCFL / unit}) \times (\text{Hg Q / CCFL})$$

3.5. Measurement of mercury quantity in output streams for mechanical treatment

This paragraph aims to specify the sampling and analysis protocols to measure total mercury quantity in all the output streams which can be present under different forms: solid, liquid and gas.

3.5.1. In solid streams

This concerns all the solid output fractions that consist of two different types:

- fractions that are intended to be recycled (pure or mixed materials) named Fractions for Recycling (**FfR**);
- fractions where the mercury is concentrated and that are directed to appropriate disposal named Fractions for Disposal (**FfD**).

In order to perform mercury quantification, please refer to the 4 *Method 3: Output fractions analyses* and particularly to 4.3 *Sampling and analysis protocol for a shredded mixed fraction of FPD*.

In order to be able to calculate the total mercury quantity present in each solid stream, the **sample sieving** operation described paragraph 4.3.1.6 shall not be done.

In fact, it will be up to the laboratory to take in charge completely the size reduction and the preparation of the sample for the mercury analysis.

Note: This may be difficult to achieve mainly for non-ferrous and ferrous parts with sizes larger than 5 mm.

n: number of Fractions for Recycling (FfR),

W FfRi: Weight of the Fraction for Recycling n°i. In case of wet process, only dry weight shall be taken into account.

Hg C FfRi: Mercury Content in the Fraction for Recycling n°i

Hg Q SFfR: total Mercury Quantity in Solid Fractions for Recycling

$$\text{Hg Q SFfR} = \sum_{i=1}^{i=n} W_{FfRi} * HgC_{FfRi}$$

p: number of Fractions for Disposal (FfD),

W FfDi: Weight of the Fraction for Disposal n°i. In case of wet process, only dry weight shall be taken into account.

Hg C FfDi: Mercury Content in the Fraction for Disposal n°i

Hg Q SFfD: total Mercury Quantity in Solid Fractions for Disposal

$$\text{Hg Q SFfD} = \sum_{i=1}^{i=p} W_{FfDi} * HgC_{FfDi}$$

Hg Q SS: total Mercury Quantity in Solid Streams

$$\text{Hg Q SS} = \text{Hg Q SFfR} + \text{Hg Q SFfD}$$

3.5.2. In liquid streams

This concerns only wet process for the liquid (until now, only closed loop system) used during the treatment of the reference batch.

At the beginning and at the end of the treatment, samples of this liquid shall be taken in order to be able to measure the 2 different mercury contents (before and after the treatment).

2 similar samples shall be taken before and after the treatment:

- the first one sent to the laboratory
- the second one kept in case of loss of the sample during transfer to the laboratory or objection to the results.

Each sample must have the same volume (0,1 liter minimum).

As for any volatile element, conditions of storage and sending must be carefully managed.

Regarding packaging, it is required to use closed airtight containers with a volume matching as close as possible the volume of the taken sample. In terms of packaging materials, PTFE (Teflon) coated or glass (Pyrex) containers shall be used. Teflon seals are also required.

The period between sampling and analysis shall not exceed 5 days.

For analysis method, please refer to EN 1483 norm.

Hg CliqB: Mercury Content in liquid Before treatment

Hg CliqA: Mercury Content in liquid After treatment

Wliq: Weight of the liquid

Hg Q CLS: total Mercury Quantity Collected in Liquid Streams

$$\text{Hg Q CLS} = \text{Wliq} \times (\text{Hg CliqA} - \text{Hg CliqB})$$

3.5.3. In gas streams

This concerns the exhaust air which has to be “depolluted” through a filtering unit (e.g. activated carbon filter) before being released.

For this mercury quantification, measuring equipment shall be installed (for more details, see 3.2.2 *Preparation of the processing units, areas and associated equipment*).

Hg CAB: Mercury Content in Air Before the filter

Hg CAA: Mercury Content in Air After the filter

AFR: Air flow Rate

Hg Q CF: total Mercury Quantity Collected by the Filter

$$\text{Hg Q CF} = \int_0^t \text{AFR}_{(t)} \times (\text{Hg CAB}_{(t)} - \text{Hg CAA}_{(t)}) \times dt$$

3.6. Mass balance calculation for mechanical treatment

3.6.1. Diagram

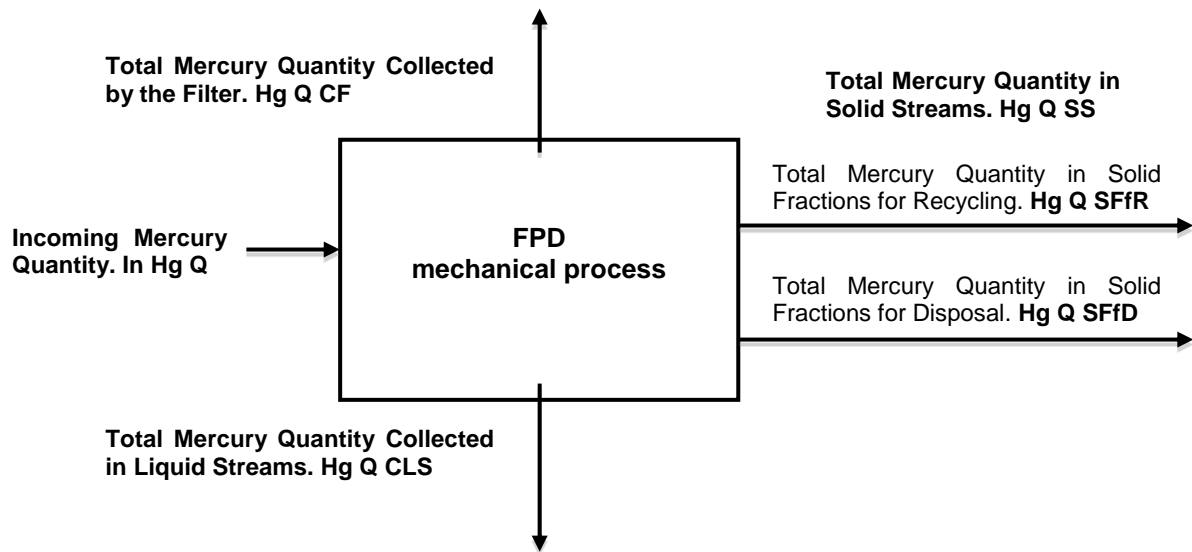


Figure 1 diagram of mass balance calculation

3.6.2. Validation of the mass balance test

The mass balance test shall be validated only if:

Losses $(In\ Hg\ Q - (Hg\ Q\ SS + Hg\ Q\ CLS + Hg\ Q\ CF))$
or gains $((Hg\ Q\ SS + Hg\ Q\ CLS + Hg\ Q\ CF)) - In\ Hg\ Q$
stay below 5% of $In\ Hg\ Q$

3.6.3. Process efficiency to reclaim mercury

This paragraph aims to define how to quantify the efficiency of the process to reclaim mercury.

Hg PE: Mercury Process Efficiency

$$Hg\ PE = (Hg\ Q\ SFfD + Hg\ Q\ CLS + Hg\ Q\ CF) / In\ Hg\ Q$$

Hg PE shall comply with the limit value specified in the WEEELABEX Treatment normative document, paragraph 5.3.1, specific requirements for the treatment of Flat Panels Displays.

4. Method 3: Output fractions analyses

4.1. Introduction

The WEEELABEX normative requirements on treatment require that de-pollution performances must be monitored (WEEELABEX normative document on Treatment, 5.4).

Monitoring of de-pollution performance shall be determined by one or several of the three following methodologies:

- quantification of the outgoing stream and comparison with a target value or assessment of progress,
- establishment of a mass balance between incoming and outgoing streams
- analysis of representative samples of relevant fractions from treatment of depolluted WEEE

This part describes the sampling and analysis protocols which have to be used to implement the third methodology.

4.1.1. Scope

Sampling and analysis protocols have been written for particular output fractions, chosen as indicators of proper de-pollution of their corresponding WEEE flows.

- **Finest non-metallic Shredder Fraction** produced from large appliances and small appliances
- **Shredded mixed fraction** from the treatment of Flat panel displays
- **Output fractions** from the treatment of CRT display appliances
- Panel glass from the treatment of CRT display appliances
- **CRT glass** from the treatment of CRT display appliances
- **Plastics** from the treatment of CRT screens, small appliances and WEEE for which the absence of BFR has not been proven

4.1.2. Normative references

4.1.2.1. Sampling norms

EN 14899: Characterization of waste – Sampling of waste materials – Framework for the preparation and application of a sampling plan.

CEN/TR 15310-1: *Guidance on selection and application of criteria for sampling under various conditions*

CEN/TR 15310-2: *Guidance on sampling techniques*

CEN/TR 15310-3: *Guidance on procedures for sub-sampling in the field*

CEN/TR 15310-4: *Guidance on procedures for sample packaging, storage, preservation, transport and delivery*

CEN/TR 15310-5: *Guidance on the process of defining the sampling plan*

4.1.2.2. Analysis norms

EN 15 308: Characterization of waste – determination of selected polychlorinated biphenyls (PCB) in solid waste by using capillary gas chromatography with electron capture or mass spectrometric detection

EPA 8082A/2007 : Polychlorinated biphenyls (PCBs) by gaz chromatography

EN 15 002: Characterization of waste – preparation of test portions from the laboratory sample

EN 13 656: Characterization of waste – Microwave assisted digestion with hydrofluoric (HF), nitric, (HNO₃) and hydrochloric (HCl) acid mixture for subsequent determination of elements

EN 13 657: Characterization of waste – Digestion for subsequent determination of aqua regia soluble portion of elements

ISO 11 885: Water quality – Determination of selected elements by inductively coupled plasma optimal emission spectrometry (ICP-OES)

ISO 17 852: Water quality – Determination of mercury – Method using atomic fluorescence spectrometry

EN 1483: Water quality – Determination of mercury – Method using atomic absorption spectrometry

EN 14582. - Characterization of waste. Halogen and sulfur content. Oxygen combustion in closed systems and determination methods

prEN 16 377: Characterization of waste – Determination of Brominated Flame Retardant (BFR) in Solid Waste

4.1.3. Terms and definitions

Population: totality of items under consideration (ISO 3534-1)

Sub-population: defined part of population (ISO 3534-1)

Sample: portion of material selected from a larger quantity of material (ISO 11074:2005)

Sampling plan (sampling protocol): Predetermined procedure for the selection, withdrawal, preservation, transportation and preparation of the portions to be removed from a population as a sample

Scale: quantity (mass or volume), defined in space and/or time, of material represented by the sample and considered relevant for the assessment of the material

On-site verification: normally simple test to evaluate if the involved waste material is indeed the type of material expected

Laboratory sample: sample sent to or received by the laboratory

GC-MS: Gas chromatography mass spectrometry

ICP-OES: Inductively coupled plasma optical emission spectroscopy

ICP-AAS: Inductively-coupled plasma atomic absorption spectroscopy

DM: dry material

Large shredder: corresponds to "End of Life Vehicles (ELV) shredders" with a treatment capacity generally over than 40 t/h

WEEE specific shredder: shredder generally designed to treat only WEEE with a treatment capacity generally below 20 t/h

4.1.4. Generalities on protocols

4.1.4.1. Sampling protocols

Principle

All the sampling protocols are based on the EN 14 899.

Sampling protocols aim at obtaining representative laboratory samples of output fractions from WEEE recycling operations.

Depending on the fractions and the substance to be analysed, two mains techniques can be used:

- Sampling from a pile
- Sampling from a falling stream

Sample taking record

A record shall be made on sample taking and it shall contain an exact description of all the operations followed during sample taking and a description of the following processing incl. a label.

4.1.4.2. Analysis protocols

Analysis protocols will be implemented by specialized laboratories. The physico-chemical analysis activity is ruled by many standards; the analysis protocols, described in this document, aim at choosing the most suitable analytical methods for each type of sample.

The analysis protocols describe the 3 main steps conducted on a laboratory sample until obtaining the results:

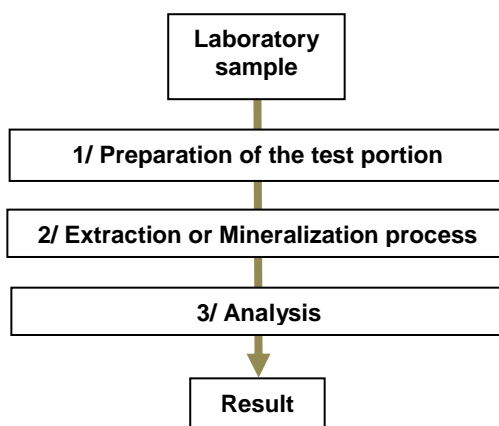


Figure 2

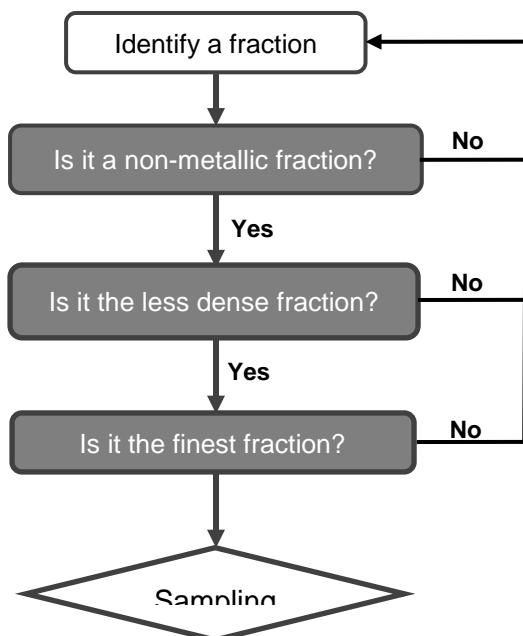
Those 3 steps are described in international and European standards. So, those analysis protocols mainly consist, for those 3 steps, in indicating which norm has to be used for each fraction and each substance.

Are also described the options to choose from when the standards provide a choice of techniques.

4.2. Sampling and analysis protocol for the finest non-metallic shredder fraction

Ref in WEEELABEX	Part 1, Annex B-3
WEEE categories	Large appliances and Small appliances
Processes concerned	Large shredder (Car shredder type) and WEEE specific shredder
Definition of the fraction to be sampled*	<p>The shredder light fraction (SLF) is the finest non-metallic shredder fraction obtained by air separation and/or screening after shredding. This fraction generally contains pieces of plastics, rubber, wood, glass and very little metal.</p> <p>Dust from dust capture systems is not concerned.</p> <p>If the process does not include a screening step (production of a shredder light fraction with a grain size over 5mm), the fraction collected will be sieved at the time of sampling before being sent to the laboratory.</p>
Substances to be analysed and limit values	PCB (50 mg/kg DM), Copper (Cu) (10000 mg/kg DM), Cadmium (Cd) (100 mg/kg DM)

Note: for WEEE specific shredder, the choice of the Shredder Light Fraction can be difficult as there is not any "fluff fraction" as produced by a car shredder. The following flowchart should help in choosing the appropriate fraction.



4.2.1. Sampling protocol

4.2.1.1. Population – Sub-population – Scale

	Reference, context	Requirement
Population	The WEEELABEX Annex B, 3.2 indicates “a representative mixed sample shall be taken and analysed at least once a year” The population can be defined as the annual production of Shredded light fraction from WEEE treatment	One analysis result per year for each treatment category of WEEE processed on the site
Subpopulations	Subpopulations should be considered only if the operator treats separately different treatment categories of WEEE (e.g. : large appliances and small appliances)	One analysis per subpopulation (i.e. per treatment category). Sampling can be performed at any moment of the year, during a treatment campaign.
Scale	It defines the mass of material that a sample directly represents.	For large shredder, the amount of SLF shall correspond to a minimum of 50 tons of input material in the recycling process. For WEEE specific shredder, the amount of SLF shall correspond to a minimum of 10 tons of input material in the recycling process. The treatment campaign whose SLF will be sampled need not be selected at random. (for example can be carried out during a batch)

4.2.1.2. Human resources and equipment

One person, familiar with the processes and sampling manipulations are required to perform the sampling protocols.

The conducting of the sampling requires the following equipment:

- Appropriate personal protective equipment as safety shoes, helmet, high visibility vest, gloves... (in accordance with the facility requirements and current regulations)
- Shovel or containers of which the unit volume is adapted to material being sampled
- Unused plastic sheeting
- Dice (to draw lots)
- Proper boxes to package samples
- Labels
- Sieve
- Tracto-loader

4.2.1.3. Number of samples

The material shall be sampled with a minimum of 10 singles samples. The 10 single samples are mixed to form a “mixed sample”. The resulting mixed sample is reduced to the size of laboratory sample.

4.2.1.4. Size of samples

The sample size depends on the particles size of the sampled fraction according to the table below.

Size of the biggest particles	Min. vol. of single sample (l)	Min. vol. of mixed sample (l)	Min. vol. of reduced sample (l)	Min. vol. of lab sample after sieving (l)
< 5 mm	0,5	5	1	1 (sieving not necessary)
5 to 20mm	1	10	2,5	1
20 to 50mm	5	50	12,5	1
> 50mm	30	300	75	1

Note: If the shredder light fraction produced by the process has a particles size over 5mm, the laboratory sample must be sieved manually until obtain the desired quantity of a “Finest non-metallic Shredder Fraction”.

4.2.1.5. Sampling method

Two sampling method can be applied, depending on the design of the process, the first one has to be chose in priority.

In both methods, the tool used for sampling must have the same minimum volume as the single sample requires in order taking it in one time.

Method 1: Sampling from a falling stream

Samples are taken at the outlet of a continuous mechanical treatment process, directly from the output flow of the fraction on the whole cross section of the flow profile.

Sampling period and sampling interval: The 10 or 50 tonnes of input material, depending on the process, should be processed as a batch. The sampling period corresponds to the processing time of 10 or 50 tonnes of input material. This period varies depending on the recycling process.

To define the sampling interval, the required processing time of the input material is divided by 10. The first sample is taken after the first tenth of the sampling period.

To take the sample, the following 3 special cases can be distinguished:

- If the width and the depth of the stream are small, put a sampling container into the stream using a single one directional action. It is recommended to place the sampling container at 90° to the falling output flow. Hold the sampling container in place for the period specified to gather the specified volume of material.
- If the width of stream is large and depth is small, insert the container at one end of the stream and, at a uniform rate designed to collect the required amount of material, move the container through the width of the stream to the opposite end.
- If width and depth of stream are large, follow the method as described above but repeat procedure at 90° to the first direction of sampling.

Method 2: Sampling from a pile

Case 1

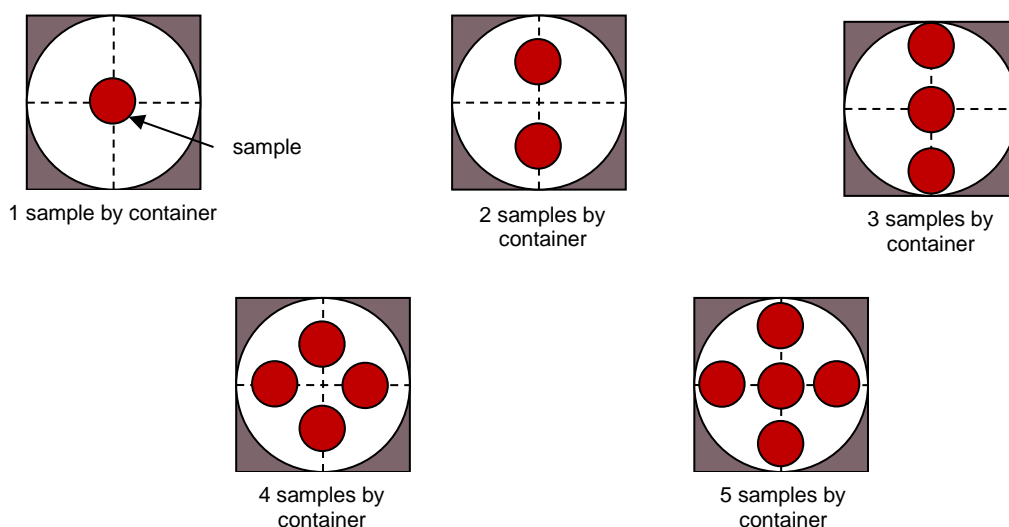
If the fraction is stored in skips, it must be emptied on the ground, in a clean space. Make the pile spread out by the operator's tracto-loader (or manually with a shovel if possible) to form a flat 50 cm high pile.

(The bucket of the tracto-loader or the shovel must be previously cleaned). Divide visually the pile in 10 equivalent parts; take 10 single samples at various depths of the heap, without taking material in contact with the ground.

The tool used for sampling must have the same minimum volume as the single sample requires in order taking it in one time. For material with large particles sizes, a large bucket may be employed.

Case 2

If the fraction is stored in containers (as pallet box) lower than 50 cm high, take the 10 single samples directly in those containers. To determine the number of sample in each container, divide 10 by the number of containers containing the fraction from the treatment of the 50 or 10 tonnes. Take the samples as indicated below.



4.2.1.6. Sample preparation and reduction

Mixed sample preparation

In a protected area, install a protective floor covering, preferably unused plastic sheeting, on the ground to avoid any contamination.

To mix the mixed sample, use the conical heap method, i.e. form a conical heap by depositing shovel by shovel (or bucket by bucket) on the peak of the new cone in such a way that the sample runs down all sides of the cone and is evenly distributed so that different particle sizes become well mixed. The size of the shovel should be of such size that this action could be repeated on at least 20 times in order to transfer the full amount of material.

Repeat the forming of a conical heap three times, to guarantee that the material is thoroughly mixed.

Mixed sample reduction

The mixed sample has to be reduced to comply with the laboratory sample size.

After having applied the conical heap method, flatten the cone to form a flat heap of uniform thickness and diameter.

Divide in four the flat heap along the two diagonals intersecting at right angles using a shovel inserted vertically into the material. Discard one pair of opposite quarters and shovel the remainder into a stockpile. Repeat this action until the volume of remaining subsample is equal to the desired size.

Sample sieving

If particles size of shredder light fraction is over 5mm, it is necessary to sieve the reduced mixed sample until obtained the required quantity of the finest non-metallic shredder fraction

If the sieving of the sample is not enough to produce the required quantity, sieve the last opposites quarters discarded, obtained at the reducing step of the mixed sample.

Sample sorting

Cadmium is analysed as an indicator to assess the removal of batteries. To avoid obtaining high cadmium concentrations due to its presence in pigments for colouring plastics, red, orange and yellow plastics must be manually removed from the sample.

4.2.1.7. Packaging and sending of samples

3 similar samples have to be done:

- The first one for the PCB analysis
- The second one for Cd and Cu analyses
- The third one kept in case of loss of the samples during transfer to the laboratory or objection to the results.

Each sample must have the same volume (see table p.26). The three samples consist in 3 quarters drawn during the last operation of quartering.

Containers should be clearly labelled. The label must contain at least the name of the recycler (or a code), WEEE stream, name of fraction and date of sampling.

Containers must be closed airtight glass containers or any other material which do not interact with PCB.

4.2.2. Analysis protocol for PCB

The laboratory must implement the standard EN 15308.

The EPA 8082A/2007 standard can also be used, in this case, use the method “quantitation of PCBs as congeners”

Below are described options to choose from when the standards provides a choice of techniques.

4.2.2.1. Test portion preparation

i- Phases separation

Not necessary

ii- Drying

Air drying at room temperature. The product must be spread out into thin layers. Be careful of the risk of contamination by dust.

If the sample is very wet (because of an outdoor storage for example), dry in oven at 40°C maximum.

iii- Size reduction

Objective: reduce from max 5mm to 1mm

Due to heat generation by grinding, the size reduction of samples for analysis of semi-volatile organic substances must be carried out by using a cryogenic technique.

The grinder used by the laboratory must be able to reduce small pieces of metal (cables, pieces of printed card board, electronic components...)

iv- Homogenization and subsampling

Mechanical subsampling to obtain a test portion between 10 and 25g.

4.2.2.2. Extraction

Hexane extraction (with agitation or ultrasonic).

Because of the risk of extracting co-substances, do not use ACETONE.

Purification phases are recommended

4.2.2.3. Analytical technique

Gas chromatography mass spectrometry shall be used.

4.2.2.4. Calculation of the total amount of PCB

The EN 15308 only gives the results for 7 congeners, it is necessary to calculate the total concentration of PCBs: apply the method of calculation outlined in of EN 12766, Part 2.

For EPA 8082A/2007, the PCB congener results may be summed and reported as total PCBs.

4.2.3. Analysis protocol for Cd and Cu

4.2.3.1. Test portion preparation

The laboratory must implement the standard EN 15 002.

i- Phases separation

Not necessary

ii- Drying

Dry in oven at 105°C

iii- Size reduction

Objective: reduce from max 5mm to 250 µm

The grinder used by the laboratory must be able to reduce small pieces of metal (cables, pieces of printed card board, electronic components...)

iv- Homogenization and subsampling

Mechanical subsampling to obtain a test portion of 200 mg

4.2.3.2. Mineralization

The laboratory must implement the standard EN 13 656.

Objective: To mineralize the entire test portion

It requires drastic safety conditions.

Two methods are available, it is preferable to conduct mineralization in semi-open containers (because materials are very reactive - among others the presence of carbon)

4.2.3.3. Analytical technique

The laboratory must implement the standard ISO 11 885 (No particular restrictions)

4.3. Sampling and analysis protocol for a shredded mixed fraction of FPD

WEEE categories	Flat Panel Displays
Processes concerned	Mechanical treatment by shredding in confined chamber
Definition of the fraction to be sampled	<p>Shredded mixed fraction (mix of de-polluted ferrous, non-ferrous metals, plastics...).</p> <p>If the process includes a step of screening, only the fine part is sampled and analysed, if it does not undergo screening, the fraction collected will be sieved at the time of sampling before being sent to the laboratory.</p>
Substances to be analysed and limit value	Mercury (Hg).(0.5mg/kg DM)

4.3.1. Sampling protocol

4.3.1.1. Population – Sub-population – Scale

	Reference, context	Requirement
Population	The population is defined as the annual production of the shredded mixed fraction from the mechanical treatment of FPD	One analysis result per year for all qualities of FPD (if several qualities treated separately, the result will be calculated as the weighted average of the different analysis results on each quality)
Subpopulations	Subpopulations should be considered only if different qualities of FPD are treated separately (e.g. ; monitors and TVs)	One analysis per subpopulation. Sampling can be performed at any moment of the year, during a treatment campaign of FPD.
Scale	It defines the mass of material that a sample directly represents.	<p>The amount of shredded mixed fraction shall correspond to a minimum of 5 tons of input material into the recycling process.</p> <p>The treatment campaign whose the fraction will be samples need not to be selected at random (for example can be carried out during a batch)</p>

4.3.1.2. Human resources and equipment

One person, familiar with the processes and sampling manipulations are required to perform the sampling protocols.

The conducting of the sampling requires the following equipment:

- Appropriate personal protective equipment as safety shoes, helmet, high visibility vest, gloves... (in accordance with the facility requirements and current regulations)
- Shovel or containers of which the unit volume is adapted to material being sampled

- Unused plastic sheeting
- Dice (to draw lots)
- Proper boxes to package samples
- Labels
- Sieve
- Tracto-loader

4.3.1.3. Number of samples

The material shall be sampled with a minimum of 10 singles samples. The 10 single samples are mixed to form a “mixed sample”. The resulting mixed sample is reduced to the size of laboratory sample.

4.3.1.4. Size of sample

The sample size depends on the particles size of the sampled fraction according to the table below.

Size of the biggest particles	Min. vol. of single sample (l)	Min. vol. of mixed sample (l)	Amount of lab. Sample (l)	Min. vol. of lab sample after sieving (l)
< 5 mm	0,5	5	1	1 (sieving not necessary)
5 to 20mm	1	10	2,5	1
20 to 50mm	5	50	12,5	1
> 50mm	30	300	75	1

Note: If the shredded mixed fraction produced by the process has a particles size over 5mm, the laboratory sample must be sieved manually until obtain the desired quantity.

4.3.1.5. Sampling method

Two sampling method can be applied, depending on the design of the process, the first one has to be chose in priority.

In both methods, the tool used for sampling must have the same minimum volume as the single sample requires in order taking it in one time.

Method 1: Sampling from a falling stream

Samples are taken at the outlet of a continuous mechanical treatment process, directly from the output flow of the fraction on the whole cross section of the flow profile.

Sampling period and sampling interval: The 5 tonnes of input material should be processed as a batch. The sampling period corresponds to the processing time of 5 tonnes of input material. This period varies depending on the recycling process.

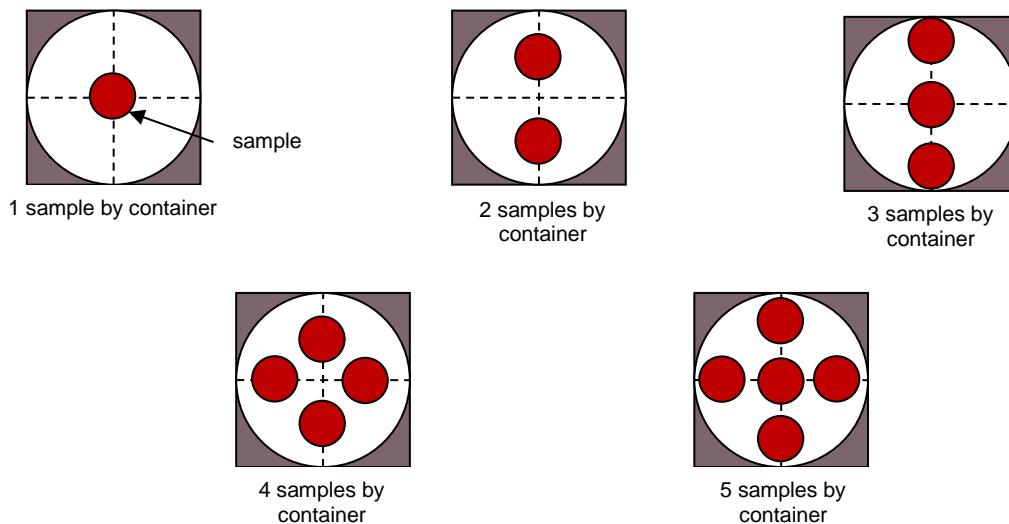
To define the sampling interval, the required processing time of the input material is divided by 10. The first sample is taken after the first tenth of the sampling period.

To take the sample, the following 3 special cases can be distinguished:

- If the width and the depth of the stream are small, put a sampling container into the stream using a single one directional action. It is recommended to place the sampling container at 90° to the falling output flow. Hold the sampling container in place for the period specified to gather the specified volume of material.
- If the width of stream is large and depth is small, insert the container at one end of the stream and, at a uniform rate designed to collect the required amount of material, move the container through the width of the stream to the opposite end.
- If width and depth of stream are large, follow the method as described above but repeat procedure at 90° to the first direction of sampling.

Method 2: Sampling from a pile

In this method, take the 10 single samples directly in containers at different depths. To determine the number of sample in each container, divide 10 by the number of containers containing the glass from the treatment of the 2 tonnes. Take the sample as indicated below:



4.3.1.6. Mixed sample preparation and reduction

Mixed sample preparation

In a protected area, install a protective floor covering, preferably unused plastic sheeting, on the ground to avoid any contamination.

To mix the mixed sample, use the conical heap method, i.e. form a conical heap by depositing shovel by shovel (or bucket by bucket) on the peak of the new cone in such a way that the sample runs down all sides of the cone and is evenly distributed so that different particle sizes become well mixed. The size of the shovel should be of such size that this action could be repeated on at least 20 times in order to transfer the full amount of material.

Repeat the forming of a conical heap three times, to guarantee that the material is thoroughly mixed.

Mixed sample reduction

The mixed sample has to be reduced to comply with the laboratory sample size.

After having applied the conical heap method, flatten the cone to form a flat heap of uniform thickness and diameter.

Divide in four the flat heap along the two diagonals intersecting at right angles using a shovel inserted vertically into the material. Discard one pair of opposite quarters and shovel the reminder into a stockpile. Repeat the process until the volume of remaining subsample is equal to the desired size.

Sample sieving

If particles size of shredder mixed fraction is over 5mm, it is necessary to sieve the reduced mixed sample until obtained the required quantity.

If the sieving of the sample is not enough to produce the required quantity, sieve the last opposites quarters discarded, obtained at the reducing step of the mixed sample.

4.3.1.7. Packaging and sending of sample

2 similar samples have to be done:

- The first one sent to the laboratory
- The second one kept in case of loss of the sample during transfer to the laboratory or objection to the results.

Each sample must have the same volume (see table p.15). The two samples consist in 2 quarters drawn during the last operation of quartering.

As for any volatile element, conditions of storage and sending must be carefully managed.

As far as packaging, it is required to use closed airtight containers with a volume as close as possible as the volume of the sample. In terms of packaging materials, PTFE (Teflon) coated or glass (Pyrex) containers must be used. Teflon seals are also required.

Sample must be sent to the laboratory in cold conditions (below 4°C).

The maximum duration between sampling and analysis must be 5 days.

4.3.2. Analysis protocol

4.3.2.1. Test portion preparation

The laboratory must implement the standard EN 15 002.

i- Phases separation
Not necessary

ii- Drying
Air drying at room temperature. The product must be spread out into thin layers. Be careful of the risk of contamination by dust.
If the sample is very wet (e.g. because of a wet process), dry in oven at 34°C maximum.

iii- Size reduction
Objective: reduce from max 5mm to 250 µm

Due to heat generation by grinding, the size reduction of samples for analysis of Hg must be carried out by using a cryogenic technique.

The grinder used by the laboratory must be able to reduce small pieces of metal (cables, pieces of printed card board, electronic components...)

iv- Homogenization and subsampling
v- Mechanical subsampling to obtain a test portion of 200 mg

4.3.2.2. Mineralization

The laboratory must implement the standard EN 13 657.

Because of a surface contamination, objective to mineralize to the maximum without the obligation to digest all the metals

This step requires drastic safety conditions.

Both closed and open vessel systems are available for digestion. In the case of mercury, closed vessels are required. EN 13657 reminds that it is also necessary to wait for a complete cooling of solution before opening the bomb.

A filtration step of the solution is needed to eliminate residues that remain after dissolution.

4.3.2.3. Analytical technique

The laboratory must implement one of the two standards below: (No particular restrictions)

ISO 17 852: Water quality – Determination of mercury – Method using atomic fluorescence spectrometry

EN 1483: Water quality – Determination of mercury – Method using atomic absorption spectrometry

4.4. Sampling and analysis protocol for glass in fractions from CRT appliances

Foreword: a visual inspection of the quality of the fractions can be sufficient to prove that the fractions are clean. This is the auditor, after inspection of fractions, who will decide whether or not to launch the implementation of the protocol and which fraction is concerned.

WEEE categories	CRT Display Appliances	
Processes concerned	Manual Dismantling of CRT display appliances and splitting of CRT	Process n°1
	Shredding of CRT	Process n°2
	Shredding of CRT display appliances	Process n°3
Definition of the fraction to be analysed	Fractions can consist in:	
	Fraction 1: Ferrous metal parts of CRT (anti-implosive metal frame, shadow masks)	Process n°1 and Process n°2
	Fraction 2: Ferrous metal parts of CRT appliance (speakers, screws, anti-implosive metal frame, shadow masks...)	Process n°3
	Fraction 3: Mix fraction after shredding and glass separation composed of metal parts, plastics, wood, deflection coil...	Process n°3
	Fraction 4: Deflection coils components (copper coil freely placed on cone that deflects electron beams emitted by electron gun)	Process n°1 and Process n°2
	Fraction 5: Electron guns	Process n°1 and Process n°2
Substances to be analysed and limit values	Residual CRT glass (on-site analysis) <ul style="list-style-type: none"> - Fraction 1 : 2% - Fraction 2 : 2% - Fraction 3 : 2% - Fraction 4 : 4% - Fraction 5 : 8%* 	

*NOTE: for electron canons, the transparent glass embedded in the base cap of the electron cannon (usually inside a plastic cap) need not to be considered for analysis.

4.4.1. Sampling protocol

4.4.1.1. Population – Sub-population – Scale

	Reference, context	Requirement
Population	The population is defined as the annual production of the concerned fraction from the treatment of CRT	One analysis result per year for all qualities of CRT (if several qualities treated separately, the result will be calculated as the weighted average of the different analysis results on each quality)
Subpopulations	Subpopulations should be considered only if different qualities of CRT are treated separately (e.g. ; monitors and TVs)	One analysis per subpopulation. Sampling can be performed at any moment of the year, during a treatment campaign of CRT.
Scale	It defines the mass of material that a sample directly represents.	<p>The amount of fraction shall correspond to a minimum of:</p> <ul style="list-style-type: none">- 5 tonnes of input material into the recycling process for manual process (process 1)- 10 tonnes of input material into the recycling process for mechanical process (process 2 and 3) <p>The treatment campaign whose the fraction will be sampled need not to be selected at random (for example, can be carried out during a batch)</p>

4.4.1.2. Human resources and equipment

One person, familiar with the processes and sampling manipulations are required to perform the sampling protocols.

The conducting of the sampling requires the following equipment:

- Appropriate personal protective equipment as safety glasses, shoes, helmet, high visibility vest, gloves... (in accordance with the facility requirements and current regulations)
- Tools to separate glass stuck to the metal frame (hammer, palette knife...)
- Dice (to draw lots)
- Tracto-loader (if necessary)
- boxes to store the separated fraction (glass)
- sorting table
- Scale - accurate to 5g units
- Labels

4.4.1.3. Sampling method for fraction 1,2,4,5

Number of samples

For the 3 types of process, the quantity of single samples is equal to the number of workstations which produce the concerned fraction in the process.

Note: A workstation is defined as a station where the concerned fractions are removed; it can be manual (dismantling), or mechanical (by an overband for example).

The single samples are mixed to form a “mixed sample”. The resulting mixed sample is reduced to the size of the sample to be analysed.

Size of sample

The size of the single samples is equal to the whole quantity of the concerned fraction produced by each workstation of the process during time of treatment of the minimum required input quantity (depending on the process considered, see scale).

Fraction	Min. size of single sample (l)	Min. size of mixed sample	Min. size of sample to be analysed
Fraction 1	equal to the quantity of the concerned fraction produced by each workstation	Sum of all the single samples	250 kg
Fraction 2			250 kg
Fraction 4			<i>A minimum of 20 deflection coils</i>
Fraction 5			<i>A minimum of 20 electron canons</i>

Sample preparation for on-site analysis

For ferrous metal, if it is stored by quality (i.e. mask and belt stored separately), in case of reduction, the sample shall be representative of the different qualities.

For deflection coils and electron canons the analysed pieces shall be taken at random directly from the treatment process and kept in a clean container before evaluation,

4.4.1.4. Sampling method for fraction 3

Number of samples

The mix fraction shall be sampled with a minimum of 10 singles samples. The 10 single samples are mixed to form a “mixed sample”. The resulting mixed sample is reduced to the size of the sample to be analysed.

Size of samples

The sample size depends on the particles size of the sampled fraction according to the table below.

Size of the biggest particles	Min. vol. of single sample (l)	Min. vol. of mixed sample (l)	Min. vol. of reduced sample (l)
< 20mm	1	10	2,5
20 to 50mm	5	50	12,5
> 50mm	30	300	75

Sampling method

Two sampling method can be applied, depending on the design of the process, the first one has to be chose in priority.

In both methods, the tool used for sampling must have the same minimum volume as the single sample requires in order taking it in one time.

Method 1: Sampling from a falling stream

Samples are taken at the outlet of a continuous mechanical treatment process, directly from the output flow of the fraction on the whole cross section of the flow profile.

Sampling period and sampling interval: The 10 tonnes of input material should be processed as a batch. The sampling period corresponds to the processing time of 10 tonnes of input material. This period varies depending on the recycling process.

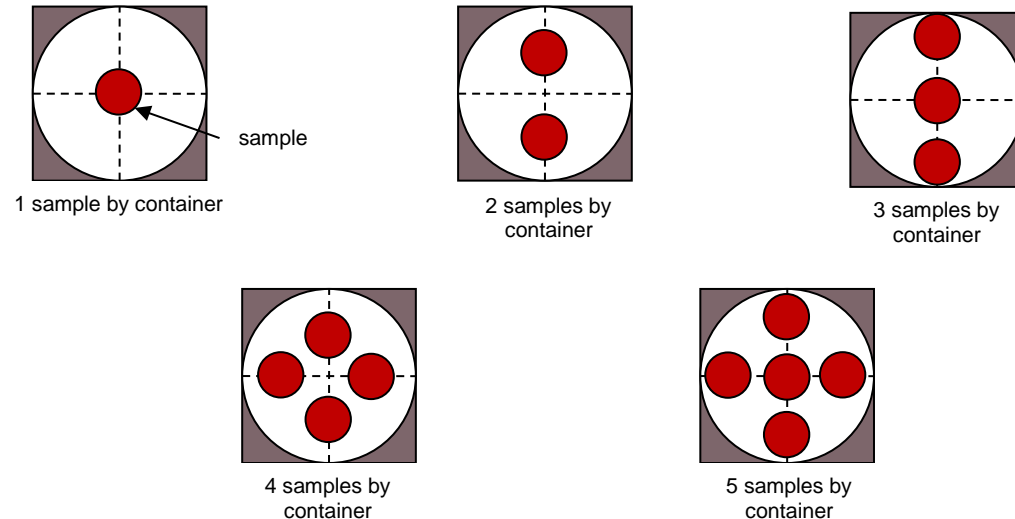
To define the sampling interval, the required processing time of the input material is divided by 10. The first sample is taken after the first tenth of the sampling period.

To take the sample, the following 3 special cases can be distinguished:

- If the width and the depth of the stream are small, put a sampling container into the stream using a single one directional action. It is recommended to place the sampling container at 90° to the falling output flow. Hold the sampling container in place for the period specified to gather the specified volume of material.
- If the width of stream is large and depth is small, insert the container at one end of the stream and, at a uniform rate designed to collect the required amount of material, move the container through the width of the stream to the opposite end.
- If width and depth of stream are large, follow the method as described above but repeat procedure at 90° to the first direction of sampling.

Method 2: Sampling from a pile

In this method, take the 10 single samples directly in containers at different depths. To determine the number of sample in each container, divide 10 by the number of containers containing the glass from the treatment of the 2 tonnes. Take the sample as indicated below:



4.4.2. On-site analysis method

The analysis is conducted on the operator's site.

4.4.2.1. Manual separation

The analysis consists in an on-site verification; the sample is separated manually between 2 categories:

- CRT glass
- Others elements

If the concerned fraction is stored in different quality, make the separation by quality. For each quality, the following operations have to be conducted:

- i. Weigh the sample to be separated;
- ii. Separate elements between the 2 categories;
- iii. Weigh the glass (M_{glass}) and others elements (M_{others}).

Note: for ferrous metal fraction, the glass is strongly stuck to the anti-implosive belt with an adhesive strip; do not separate glass from adhesive strips. Adhesive strip represents about 2% of the weight of the glass removed from the belt. A correction factor shall be applied.

4.4.2.2. Calculation of the glass contents

G: Glass content

$M_{\text{glass } i}$: Mass of residual glass for each quality of the concerned fraction

$M_{\text{others } i}$: Mass of others elements for each quality of the concerned fraction

For belt in ferrous metal fraction, calculate a corrected mass: $M_{\text{glass cor}} = M_{\text{glass cor}} \times 0.98$

If all kinds of ferrous metal quality are mixed, apply the same correction factor to the mix of glass.

$$G = \sum M_{\text{glass } i} / (M_{\text{others } i} + M_{\text{glass } i})$$

4.5. Sampling and analysis protocol for the panel glass fractions from CRT display appliances

Ref in WEEELABEX	Part 2, Specific requirements for the treatment of CRT display appliances	
WEEE categories	CRT display appliances	
Processes concerned	Splitting of CRT	Process n°1
	Mechanical shredding of CRT/CRT display appliance and separation between panel glass and funnel glass	Process n°2
Definition of the fraction to be sampled	Panel glass (also sometimes called front glass) : glass from front part of CRT with high content of barium oxide and strontium oxide	
Substances to be analysed and limit values	Lead oxide (PbO) < 0,5 wt %	

4.5.1. Sampling protocol

4.5.1.1. Population – Sub-population – Scale

	Reference, context	Requirement
Population	The population is defined as the annual production of panel glass from the treatment of CRT	One analysis result per year for all qualities of CRT (if several qualities treated separately, the result will be calculated as the weighted average of the different analysis results on each quality)
Subpopulations	Subpopulations should be considered only if different qualities of CRT are treated separately (e.g. ; monitors and TVs)	One analysis per subpopulation. Sampling can be performed at any moment of the year, during a treatment campaign of CRT.
Scale	It defines the mass of material that a sample directly represents.	The amount of panel glass shall correspond to a minimum of 5 tonnes of input material into the manual process and a minimum of 10 tonnes of input material into the mechanical process. The treatment campaign whose the fraction will be sampled need not to be selected at random (for example, can be carried out during a batch).

4.5.1.2. Human resources and equipment

One person, familiar with the processes and sampling manipulations are required to perform the sampling protocols.

The conducting of the sampling requires the following equipment:

- Appropriate personal protective equipment as safety shoes, helmet, high visibility vest, gloves... (in accordance with the facility requirements and current regulations)
- Shovel or containers of which the unit volume is adapted to material being sampled
- Unused plastic sheeting
- Dice (to draw lots)
- Proper boxes to package samples
- Labels

4.5.1.3. Number of samples

The material shall be sampled with a minimum of 10 singles samples. The 10 single samples are mixed to form a "mixed sample". The resulting mixed sample is reduced to the size of laboratory sample.

4.5.1.4. Size of samples

The sample size depends on the particles size of the sampled fraction according to the table below.

Size of the biggest particles	Min. vol. of single sample (l)	Min. vol. of mixed sample (l)	Min. vol. of reduced sample (l)
< 5 mm	0,5	5	0,5
5 to 20mm	1	10	1
20 to 50mm	3	30	3
> 50mm	10	100	10

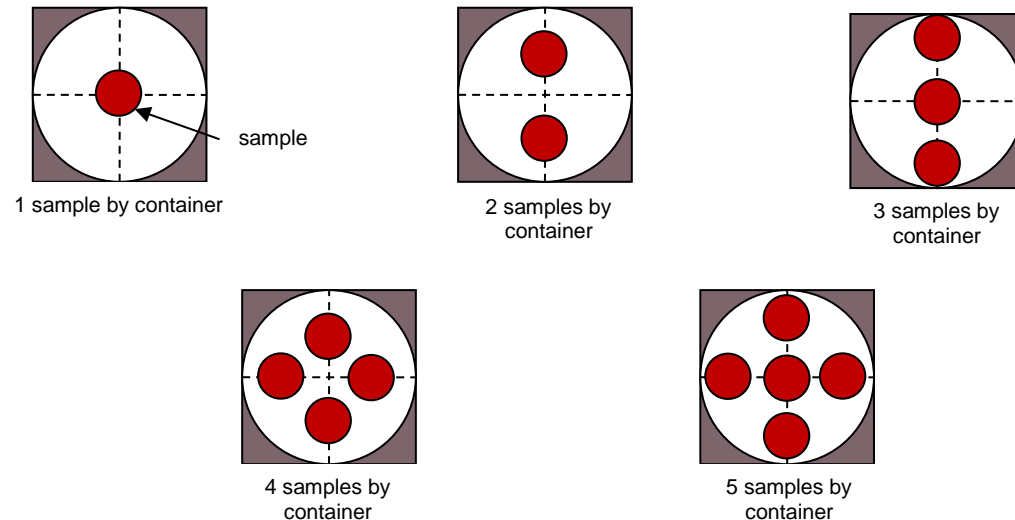
4.5.1.5. Sampling method

Two sampling method can be applied, depending on the design of the process, the first one has to be chose in priority.

In both methods, the tool used for sampling must have the same minimum volume as the single sample requires in order taking it in one time.

Process 1 and 2: Sampling from containers

Take the 10 single samples directly in containers. To determine the number of sample in each container, divide 10 by the number of containers containing the fraction from the treatment of the 5 or 10 tonnes. Take the samples in the containers as indicated below.



Process 2: Sampling from a falling stream

Samples are taken at the outlet of a continuous mechanical treatment process, directly from the output flow of the fraction on the whole cross section of the flow profile.

Sampling period and sampling interval: The 10 tonnes of input material, depending on the process, should be processed as a batch. The sampling period corresponds to the processing time of 10 tonnes of input material. This period varies depending on the recycling process.

To define the sampling interval, the required processing time of the input material is divided by 10. The first sample is taken after the first tenth of the sampling period.

To take the sample, the following 3 special cases can be distinguished:

- If the width and the depth of the stream are small, put a sampling container into the stream using a single one directional action. It is recommended to place the sampling container at 90° to the falling output flow. Hold the sampling container in place for the period specified to gather the specified volume of material.
- If the width of stream is large and depth is small, insert the container at one end of the stream and, at a uniform rate designed to collect the required amount of material, move the container through the width of the stream to the opposite end.
- If width and depth of stream are large, follow the method as described above but repeat procedure at 90° to the first direction of sampling.

4.5.1.6. Sample preparation and reduction

Mixed sample preparation

In a protected area, install a protective floor covering, preferably unused plastic sheeting, on the ground to avoid any contamination.

To mix the mixed sample, use the conical heap method, i.e. form a conical heap by depositing shovel by shovel (or bucket by bucket) on the peak of the new cone in such a way that the sample runs down all sides of the cone and is evenly distributed so that different particle sizes become well mixed. The size

of the shovel should be of such size that this action could be repeated on at least 20 times in order to transfer the full amount of material.

Repeat the forming of a conical heap three times, to guarantee that the material is thoroughly mixed.

Mixed sample reduction

The mixed sample has to be reduced to comply with the laboratory sample size.

After having applied the conical heap method, flatten the cone to form a flat heap of uniform thickness and diameter.

Divide in four the flat heap along the two diagonals intersecting at right angles using a shovel inserted vertically into the material. Discard one pair of opposite quarters and shovel the remainder into a stockpile. Repeat this action until the volume of remaining subsample is equal to the desired size.

4.5.1.7. Packaging and sending of samples

2 similar samples have to be done:

- The first one for the laboratory
- The second one kept in case of loss of the samples during transfer to the laboratory or objection to the results.

Each sample must have the same volume. The two samples consist in 2 quarters drawn during the last operation of quartering.

Containers should be clearly labelled. The label must contain at least the name of the recycler (or a code), WEEE stream, name of fraction and date of sampling.

4.5.2. Analysis protocol for Pb and PbO

The laboratory analyses focus on lead (Pb) and if possible on lead oxide (PbO) quantity.

4.5.2.1. Test portion preparation

The laboratory must implement the standard EN 15 002.

v- Phases separation

Not necessary

vi- Drying

If necessary, dry in oven at 105°C

vii- Size reduction

Objective: reduce from max 5mm to 250 µm

viii- Homogenization and subsampling

Mechanical subsampling to obtain a test portion of 200 mg

4.5.2.2. Mineralization

The laboratory must implement the standard EN 13 657.

Objective: To mineralize the entire test portion

4.5.2.3. Analytical technique

The laboratory must implement the standard ISO 11 885 (No particular restrictions)

4.5.2.4. Results

The laboratory will give two results:

- Pb (mg/kg DM)
- PbO (mg/kg DM)

If the laboratory doesn't calculate the lead oxide content, determine the lead oxide contents as following:

L: Lead oxide content (mg/kg)

Q_{Pb}: Lead quantity in the sample – results from laboratory (mg/kg)

$$L = Q_{Pb} \times (1 + 0.07722)$$

4.6. Sampling and analysis protocol for CRT glass after the removal of fluorescent coatings

WEEE categories	CRT Display Appliances	
Processes concerned	Splitting of CRT and removal of fluorescent coatings by vacuum cleaner	Process n°1
	Cleaning of CRT glass in a dry environment	Process n°2
	Cleaning of CRT glass in a wet environment	Process n°3
Definition of the fraction to be analysed	Different fractions of cleaned CRT glass:	
	panel glass (also sometimes called front glass)	Process n°1
	panel glass or mixed CRT glass	Process n°2
	panel glass or mixed CRT glass	Process n°3
Substances to be analyzed and limit value	Residual Sulphur in fractions of CRT glass after de-pollution operations as an indicator of the fluorescent coatings residuals	
	Sulphur content < 5mg/kg DM of glass	

Introduction

On the glass from cathode ray tubes (CRT) there are fluorescent coatings, which may contain hazardous heavy metals.

We hereby put forward a detailed description of the sample taking procedures with the following chemical analysis of the residual content of the fluorescent coatings in the product of the cleaned glass. The decisive element to determine the degree of fluorescent coatings removal is the residual content of S (Sulphur). The content of S in fluorescent coatings is relatively constant (approx. 21 %) and S is presented ONLY in the fluorescent coatings as ZnS.

Objective

The objective is to measure efficiency of various used methods of fluorescent coatings removal. The objective is to determine average contents of the residual S and to find out the efficiency of the particular procedure.

4.6.1. Sampling protocol

4.6.1.1. 1.1 Population – Sub-population – Scale

	Reference, context	Requirement
Population	The population is defined as the annual production of the panel glass / mixed CRT glass from the treatment of CRT / CRT display appliance	One analysis result per year for all qualities of CRT / CRT display appliance (if several qualities treated separately, the result will be calculated as the weighted average of the different analysis results on each quality)
Subpopulations	Subpopulations should be considered only if different qualities of CRT are treated separately (e.g. ; monitors and TVs)	One analysis per subpopulation. Sampling can be performed at any moment of the year, during a treatment campaign of CRT.
Scale	It defines the mass of material that a sample directly represents.	<p>The amount of the panel / mixed CRT glass shall correspond to a minimum of:</p> <ul style="list-style-type: none">- 3 tonnes of input material into the treatment process for manual process (process 1)- 6 tonnes of input material into the recycling process for mechanical process (process 2,3) <p>The treatment campaign whose the fraction will be sampled need not be selected at random. (for ex. can be carried out during a batch)</p>

4.6.1.2. Human resources and sample taking equipment

One person, familiar with the processes and sampling manipulations are required to perform the sampling protocols.

The conducting of the sampling requires the following equipment:

- Appropriate personal protective equipment as safety glasses, shoes, helmet, high visibility vest, gloves... (in accordance with the facility requirements and current regulations)
- Labels
- Tools suitable for particular types of glass depending on the technological procedure to be used (plastic or metal shovels of various sizes, sampling vessels, quarter crosses, brooms and brushes). These must be solid, clean and easy to wash.

4.6.1.3. Number of samples

A minimum of 5 single samples shall be randomly taken from the fraction to be analysed. The samples shall be selected and taken in accordance with the clause A.2.5 of the TS 50625-3-1.

4.6.1.4. Size of samples

The sample size depends on the particles size of the sampled fraction according to the table below.

4.6.1.5. Sampling method

The samples shall be directly taken of the size required for the analysis without any reducing and homogenization process. The sample size should be approximately 1,5 kg (or equivalent volume).

4.6.1.6. Detailed description and sampling place for the particular procedures

Process n.1: Sample taking of the glass cleaned by a vacuum cleaner

This is a procedure with the splitting of the tube into the cone parts (funnel glass with coatings) and screen parts (panel glass with coatings) and removal of the metal shadow mask. The very removal of fluorescent coatings from panel glass is done by a brush and at the same time the vacuum cleaner is intensively exhausting with the material being captured in the filter. The cleaned screen part - panel glass is dispatched in the form of a complete part or as broken pieces.

Break manually whole screen parts to get broken pieces of less than 50 mm.

Process n. 2: Sample taking of the glass cleaned in a dry way by grinding

This is a technological procedure when after the tube destruction the metal Fe shadow mask is removed from the tube and the glass is cleaned by dry grinding. Fluorescent and other coatings are continually exhausted and captured in the filter. The cleaned glass is of the category MIX (mixture of panel and funnel glass). The output fraction from the process is either of the category MIX (mixture of panel and funnel glass) or of separated fraction of panel and fraction of funnel glass.

The efficiency of the process will be determined by taking samples of the product of panel glass preferably or mixed CRT glass.

Process n. 3: Sample taking of the glass cleaned in a wet way by grinding

Fluorescent coatings are removed from the CRT glass by grinding in water medium and pass into the water in the form of sludge. The output fraction from the process is either of the category MIX (mixture of panel and funnel glass) or of separated fraction of panel and fraction of funnel glass.

The efficiency of the process will be determined by taking samples of the product of panel glass preferably or mixed CRT glass.

Reasoning for not analyzing the funnel glass:

- The panel glass is primarily a carrier of fluorescent coatings and the object of its removal
- The panel glass corresponds to the largest weight fraction of processed CRTs
- It can be assumed that the content of residual fluorescent coatings on funnel glass from the process will always be lower than on panel glass

4.6.1.7. Sample analysis

All 5 single samples shall be analysed according to the following analysis protocol. All five samples randomly collected and analysed shall meet the limit value for sulphur of 5mg/kg DM.

4.6.2. Analysis protocol

(Scale adapted for 1.5 kg sample)

From the methodological point of view this analysis protocol will define the extraction of the residual content of fluorescent coatings from the surface of the glass with the hydrochloric acid in a solution, and determine the content of S in a liquid sample.

4.6.2.1. Sample description

The sample should be raw CRT glass pieces without grinding, from the fluorescent coatings removal process. Ideal sample: broken pieces of CRT glass after the removal of fluorescent coatings.

In the case of grinding/milling, it is difficult to ensure the homogeneity of the sample; after grinding, the fluorescent coatings particles are in a form of freely flowing dust, which separates from the glass particles because of the density difference. This dust easily adheres to hairy surfaces (like filter paper), thus all manipulations with grinded samples should be performed on smooth surfaces (like lab plates).

Approximate geometry/size of cullet: about 6 x 6 cm, in order to pass the mouth of leaching vessel.

4.6.2.2. Sample weight reduction in laboratory

When an amount of material surpassing 1, 5 kg is supplied (according to table in section 1.3.2); a sample weight reduction by quartation is performed. The whole process should be performed on a smooth surface, preferably by manual division of cullet into four piles (taking care not to wipe away fluorescent coatings residuals from the inner surface of the cullet).

4.6.2.3. Acid used for leaching:

Aqueous hydrochloric acid is prepared by mixing 1 volume part of conc. aq. HCL of highest purity (for analysis) with 4 volume parts of distilled or demi water. The concentration of such HCL is about 8 % (w/w). For example, 500 ml of conc. HCL is added in one portion into 2000 ml of water in a glass bottle of 2,5L capacity in a fume board. After mixing and cooling to room temperature, the acid is ready for use. This volume of acid is sufficient for leaching five samples.

4.6.2.4. Leaching procedure:

In a fume board, evolution of smelly H₂S. The glass SAMPLE is put into a wide mouth PE bottle of 1000 ml volume (low type, like www.thermofisher.cz part No. 2108.2116) and weighted with precision on the first decimal point. It is easily possible to introduce about 1500 g of glass.

Hydrochloric acid (500 ml, see above) is added quickly in one portion on the sample in the vessel. The vessel is tightly closed with a screw cap and tightened with Parafilm. The vessel is left in an ultrasonic bath for 15 min at room temperature, occasionally taking away and swirling upside down. Then it is let to stand at room temperature for 15 min with occasional swirling upside down. After final swirling, the LEACHATE is taken with a syringe of 10 ml capacity, filtered through a syringe filter of 0,45 µm porosity into a plastic test tube and tightly closed by a well-fitting stopper. The sulphur content is analysed ASAP, not later than one hour. When analysing more samples, all samples should be worked up, leached and analysed in one run (altogether).

4.6.2.5. Quantification technique:

The sulphur content is quantified on ICP EOS instrument using 182.0 nm wavelengths for sulphur. Instrument setting: axial plasma, glass concentric nebuliser chamber, E-pond nebuliser type PFA-uFLOW 100, nebuliser pressure 25 p.s.i. More than 2 h washing of the optic box by argon stream (182.0 nm is in far UV region). Sample uptake 2, 30 ml/min, RF power for plasma 1150 W.

4.6.2.6. Sulphur standard

In the leachate, the sulphur is present as volatile hydrogen sulphide, for this reason, ordinary accessible sulphur standards (generally containing sulphur as sulphate) can NOT be used for calibration. Only the standards containing sulphur as a sulphide can be used (see e.g., <http://www.sigmaaldrich.com> part No. ICS023-100 ML).

A different procedure can also be used to prepare the standard solution:

The calibration standard is prepared by dissolution of 7.5 g of sodium sulphide Nona hydrate (first quality, fresh, for example Sigma Aldrich cat. No. 14738) in 100 ml of water. The exact content of sulphur in this basic solution is quantified by ICP EOS using the ordinary standard for calibration, or by redox titration.

4.6.2.7. Calibration

From this starting 1000 ppm S solution, calibration solutions containing 5, 10, 20 and 40 ppm S should be prepared by taking 1 ml of the starting solution and adding it into volumetric flasks (of 200, 100, 50 and 25 ml capacity) containing HYDROCHLORIC ACID (the same acid as for leaching procedure, see above). Flasks should be filled to the mark, and solutions should be mixed. Hydrochloric acid is also used as a blank.

4.6.2.8. Detection limit of Sulphur in leachate

The limit of detection is 0, 02 ppm sulphur in the solution measured.

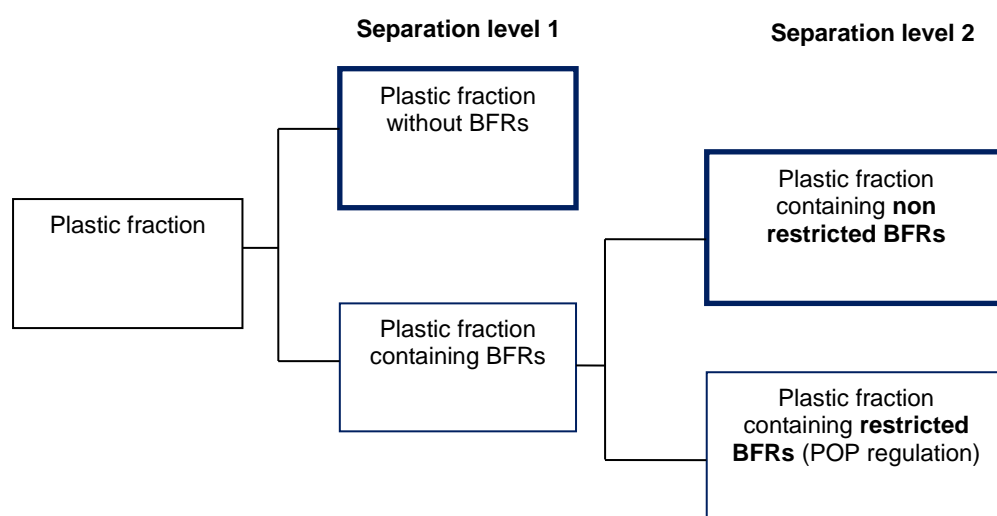
4.7. Sampling and analysis protocol for plastics

WEEE categories	<ul style="list-style-type: none"> - SHA - CRT Screens - All WEEE for which the absence of Brominated Flamme Retardant (RFBs) has not been proven
Processes concerned	Separation of plastic containing BFRs (optical sorting and flotation bath)
Definition of the fraction to be sampled	<p>De-pollution monitoring shall take place with materials that are generated from fractions that might contain the BFRs :</p> <ul style="list-style-type: none"> - For CRT: all fractions that are likely to contain at least 50% by mass of plastic. - For SHA : all fractions that represent at least 10% by mass of the input appliances and are likely to contain at least 50% of plastic - For other type of WEEE : all fractions that are likely to contain at least 10% by mass of plastic <p>Depending on the process, this protocol can be applied on :</p> <ul style="list-style-type: none"> - Plastics fraction after BFRs have been removed - Plastics fraction after restricted BFRs have been removed
Product sample and threshold value	<p>Depending on the process, the limit value are :</p> <ul style="list-style-type: none"> - For plastic fraction without BFR: 2000 ppm of Bromine <p>As a complementary way of control of the analysis results, the depollution rate is calculated, but neither target is defined.</p>

This protocol aims to control that plastics from WEEE containing BFR are properly depolluted. According to the CENELEC Standard, depending on the available technology, two degrees of separation can be applied by operators:

- Removal of Plastic fraction containing BFRs
- Removal of Plastic fraction containing restricted BFRs (POP regulation)

The next figure show the final fractions obtained in both cases.



According to the annex B “Depollution monitoring” of the CENELEC Standard, an appropriate statistical sampling and analysis shall be carried out on plastic fractions not containing BFRs that have been segregated.

This protocol also aims to check the depollution efficiency of the process by measuring the concentration in BFRs (or restricted BFRs) in the input fraction and compare the result with the output fraction.

To control the separation level 1: The method consists in measuring the concentration of bromine of a sample of the input fraction and the depolluted plastic fraction (declared as free of BFRs). Those analyses shall be done by a laboratory.

To control the separation level 2: The method consists in measuring the concentration of restricted BFRs of a sample of the input fraction and of the depolluted plastic fraction (declared as free of restricted BFRs). Those analyses shall be done by a laboratory.

Both methods can be applied on a mix of plastic or separated resins (ABS, PS...).

In case of auto-control or need to get an immediate result, another analytical method can be applied. It consists in measuring the mass of brominated plastics fraction present in the input fraction and still present in the depolluted plastics (declared as free of BFR). This analysis shall be done on-site. Results obtained by this method are only indicative and not sufficient to prove that plastics comply with the standard as the PP and PE plastics containing BFRs are not detected by this method (PE and PP represent a small part of the plastic of WEEE). This method can be used as a process monitoring tool.

In this case, the limit values are:

- A maximum of 3,3%¹ by mass of plastics containing BFRs in depolluted plastics.
- Plastic pieces considered as not containing BFRs shall not contain bromine at a concentration above 3%² (30 000ppm).

The complete description of this method is presented in appendix of this document.

4.7.1. Sampling protocol

The sampling protocol is similar for plastics from separation level 1 or separation level 2. Two samples shall be done; one on the input fraction, one on the output fraction declared as free of BFRs (or restricted BFRs).

¹ Considering an average concentration of bromine of 6%¹ in brominated plastics, a maximum concentration of 2000 ppm is equivalent to 3,3% of brominated plastic in a batch of plastic. ($2000 / 60000 = 3,3\%$)

² Temporary limit value

4.7.1.1. Population - sub-population - scale

	Définition	Requirement
Population	The population is defined as the annual production of plastic declared free of BFRs (or restricted BFRs)	It will be done at a minimum rate of an analysis per year
Sub-populations	Sub-populations should be considered only if the operator treats separately different treatment categories of WEEE (e.g. : Large appliances and small appliances)	An analysis by sub-population present on the treatment facility. The analysis can be performed at any time of the year during a treatment campaign.
Scale	It defines the mass of material that a sample directly represents.	The amount of depolluted plastic to be analysed shall correspond to a minimum of 10 tonnes of input material into the recycling process. The 10 t of plastic to be sampled need not to be selected at random in the whole population. (for example, can be carried out during a batch)

4.7.1.2. Human and material means required

The sampling will be conducted by a person familiar with the processes involved and the manipulation of samples.

The implementation of the sampling and analysis requires the following equipment:

- Suitable PPE (gloves, vest high-visibility, shoes) in accordance with the safety requirements of the treatment plant and the legislation in use.
- 1 Unused plastic sheeting
- 1 shovel
- containers of 3, 5 or 10 litres capacity, depending of the particle size of the plastic
- 1 dice (to draw lots)
- containers suitable for the conditioning and sending of the samples
- Labels

4.7.1.3. Number and size of the samples

Both input fraction and fraction declared as free of BFRs are sampled with a minimum of 10 single samples. These 10 single samples are mixed in order to form a mixed sample, which is then reduced at the size of the sample to be analyzed.

Size of the biggest particles	Single sample volume (l)	Mixed sample volume (l)	Reduced sample for laboratory analysis (l)
< 20 mm	3	30	7,5
20 to 50 mm	5	50	12
> 50 mm	10	100	25

4.7.1.4. Sampling method

The quantity of input material according to the recycling process should be processed as a batch.

The tool used for sampling must have the same minimum volume as the single sample requires in order taking it in one time.

Two sampling methods can be applied:

- For the input fraction, the second one is generally the only one which is applicable
- For the output fraction the first one has to be chosen in priority if it is possible to implement.

- Method 1: Sampling from a falling stream

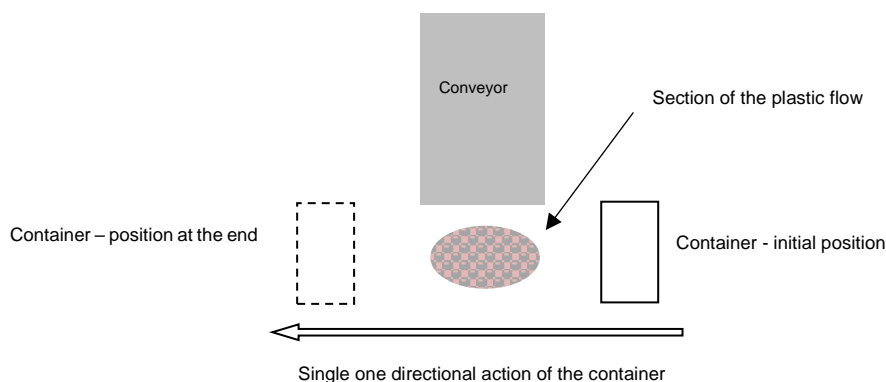
Samples are taken at the outlet of a continuous mechanical treatment process, directly from the output flow of the fraction on the whole cross section of the flow profile.

Sampling period and sampling interval: The 10 tonnes of input material, depending on the process, should be processed as a batch. The sampling period corresponds to the processing time of 10 tonnes of input material. This period varies depending on the recycling process flowrate.

To define the sampling interval, the required processing time of the input material is divided by 10. The first sample is taken after half of the time of the first tenth of the sampling period.

To take the sample, the following 3 special cases can be distinguished:

- If the width and the depth of the stream are small, put a sampling container into the stream using a single one directional action. It is recommended to place the sampling container at 90° to the falling output flow. Hold the sampling container in place for the period specified to gather the specified volume of material.
- If the width of stream is large and depth is small, insert the container at one end of the stream and, at a uniform rate designed to collect the required amount of material, move the container through the width of the stream to the opposite end. (See example below)
- If width and depth of stream are large, follow the method as described above but repeat procedure at 90° to the first direction of sampling.



- Method 2: Sampling from a pile

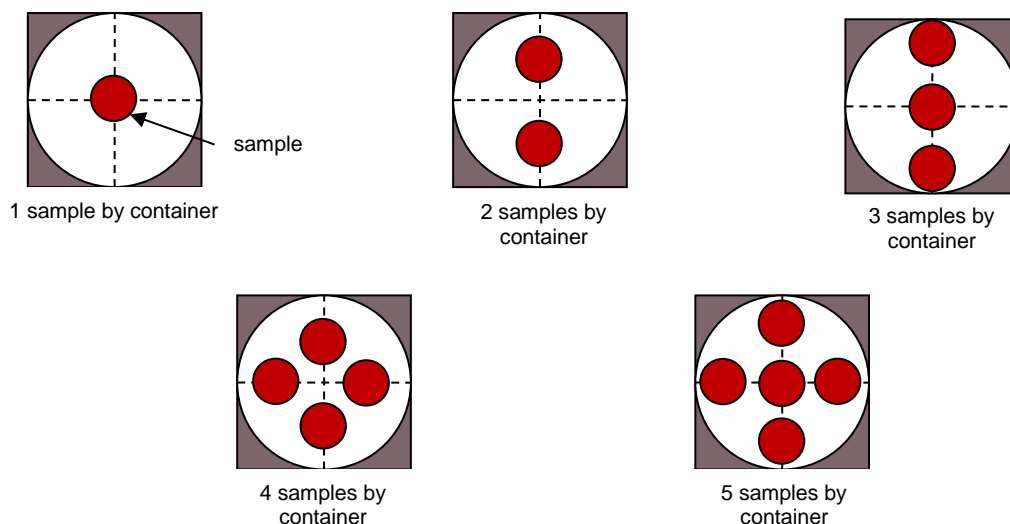
Case 1

If the fraction is stored in skips or big-bags, it must be emptied on the ground, in a clean space. Make the pile spread out by the operator's tracto-loader (or manually with a shovel if possible) to form a flat 50 cm high pile. (The bucket of the tracto-loader or the shovel must be previously cleaned). Divide visually the pile in 10 equivalent parts; take 10 single samples at various depths of the heap, without taking material in contact with the ground.

The tool used for sampling must have the same minimum volume as the single sample requires in order taking it in one time. For material with large particles sizes, a large bucket may be employed.

Case 2

If the fraction is stored in containers (as pallet box) lower than 50 cm high, take the 10 single samples directly in those containers. To determine the number of sample in each container, divide 10 by the number of containers containing the fraction from the treatment of the 10 tonnes. Take the samples as indicated below.



4.7.1.5. Preparation and reduction of the sample

▪ **Mixed sample preparation**

In a protected area, install a protective floor covering, preferably unused plastic sheeting, on the ground to avoid any contamination.

To homogenize the mixed sample, use the conical heap method, i.e. form a conical heap by depositing shovel by shovel (or bucket by bucket) on the peak of the new cone in such a way that the sample runs down all sides of the cone and is evenly distributed so that different particle sizes become well mixed. The size of the shovel should be of such size that this action could be repeated on at least 20 times in order to transfer the full amount of material.

Repeat the forming of a conical heap three times, to guarantee that the material is thoroughly mixed.

▪ **Mixed sample reduction**

The mixed sample has to be reduced to comply with the laboratory sample size.

After having applied the conical heap method, flatten the cone to form a flat heap of uniform thickness and diameter.

Divide in four the flat heap along the two diagonals intersecting at right angles using a shovel inserted vertically into the material. Discard one pair of opposite quarters and shovel the remainder into a stockpile. Repeat the process until the volume of remaining subsample is equal to the desired size.

From the same reduction operation, form 2 samples:

- The first one for the Bromine analysis in laboratory

- The second one kept in case of loss of the samples during transfer to the laboratory or objection to the results.

- **Packaging and sending of samples**

Containers should be clearly labelled. The label must contain at least the name of the recycler (or a code), WEEE stream, name of fraction and date of sampling.

4.7.2. Analysis protocol

Depending on the process two different analysis protocols shall be implemented:

- Sorting of plastics fraction between plastics containing BFRs and non-containing BFRs
- Sorting of plastic fraction between plastics containing restricted BFRs and no restricted BFRs

4.7.2.1. Sorting of plastics fraction between plastics containing BFRs and non-containing BFRs

To calculate the depollution rate, this part of the protocol shall be implemented on the input fraction and the output fraction

Analyzes shall be run in triplicate. The whole mass of the laboratory sample shall be reduced to prepare the test portions.

Test portion preparation

The laboratory must implement the standard EN 15 002 to prepare 3 test portions of 2g with a maximum size of 200µm.

To avoid plastics melt in the grinder, a cryogenic technique is strongly recommended.

Analytical technique

The laboratory must implement the standard EN 14582. (Characterization of waste. Halogen and sulfur content. Oxygen combustion in closed systems and determination methods)

The analysis result is the average of the three results. If one of the three values seems to be outlier, just consider the two others.

4.7.2.2. Sorting of plastics plastic fraction between plastics containing restricted BFRs and non-restricted BFRs

This protocol shall be implemented on the input fraction and the output fraction.

Analyzes shall be run in triplicate. The whole mass of the laboratory sample shall be reduced to prepare the test portions.

Test portion preparation

The laboratory must implement the standard EN 15 002 to prepare 3 test portions of 2g with a maximum size of 500µm.

To avoid plastics melt in the grinder, a cryogenic technique is strongly recommended.

Analytical technique

The laboratory must implement the standard prEN 16377 (Characterization of waste - Determination of Brominated Flame Retardants (BFR) in Solid Waste)

This Standard specifies a method for the determination of selected BFRs, in waste materials using gas chromatography/mass spectrometry (GC/MS) in the electron impact (EI) ionisation mode (GC-EI-MS).

BFRs to be analyzed are 4 PBDE and 1 PBB

- Tetrabromo diphenyl ether
- pentabromo diphenyl ether
- hexabromo diphenyl ether
- heptabromo diphenyl etherhexabromo biphenyl

4.7.2.3. Calculation of the analytical results and comparison to the limit value

In case of separation level 1

The analysis result is the average of the three results obtained from the 3 test portions. If one of the three values seems to be outlier, just consider the two others.

the result is compared to the limit value, 700 ppm

Depollution rate is equal to $= 1 - (\text{Analysis result in the input} / \text{Analysis result in the output})$

In case of separation level 2

The sum of the concentration of the 5 molecules is considered as the concentration in total restricted BFRs

The analysis result is the average of the three results obtained from the 3 test portions. If one of the three values seems to be outlier, just consider the two others.

- The sum of restricted BFR is compared to the limit value, 1000 ppm
- The concentration of Hexabromo biphenyl is compared to 50 ppm

Appendix 1: On-site method

Sampling protocol

Human and material means required

The sampling will be conducted by a person familiar with the processes involved and the manipulation of samples.

The implementation of the sampling and analysis requires the following equipment:

- Suitable PPE (gloves, vest high-visibility, shoes) in accordance with the safety requirements of the treatment plant and the legislation in use.
- 1 Unused plastic sheeting
- 1 shovel et 1 dustpan
- containers of 3, 5 or 10 litres capacity, depending of the particle size of the plastic
- 1 dice
- containers suitable for the conditioning and sending of the samples
- Labels
- 10mm sieve
- 1 balance (range 50 kg; accuracy of 1 g)
- The portable flottation device
- A unit of on-site bromine analysis (*Fluorescence X / LIBS / Sliding Spark Spectrometer*)

Number and size of the samples

Both input fraction and output fraction declared as free of BFRs are sampled with a minimum of 10 single samples. These 10 single samples are mixed in order to form a mixed sample, which is then reduced at the size of the sample to be analyzed.

Size of the biggest particles	Single sample volume (l)	Mixed sample volume (l)	Reduced sample for on-site analysis (after sieving) (l)
< 20 mm	3	30	7,5
20 to 50 mm	5	50	12
> 50 mm	10	100	25

Sampling method

Ditto method described in 1.4 of *Sampling and analysis protocol for plastics*.

Preparation and reduction of the sample

▪ Mixed sample preparation

Ditto method described in 1.5.1 of *Sampling and analysis protocol for plastics*.

▪ Mixed sample reduction

Ditto method described in 1.5.2 of *Sampling and analysis protocol for plastics*.

▪ **Sample sieving**

This operation is implemented on the sample formed to the on-site analysis. If plastic contains particles whose size is below 10mm, the sample will be sieved at 10mm. Pieces smaller than 10mm are discarded.

Analysis protocol

The analysis consists in measuring the mass of residual brominated plastics still present in the depolluted plastics. To aim this result, the presence of bromine is checked in each piece. A first separation by flotation (separation by density) is possible to limit the quantity of pieces to analyze; only densest plastic pieces will be potentially considered as brominated (see the diagram in the appendix 2).

For the bromine analysis, one of the following analytical methods may be used: Fluorescence X / LIBS / Sliding Spark Spectrometer.

The flotation process

The first stage consists in a flotation of the plastic in water. This operation is necessary to separate wood, foam and other light impurities. It is also useful to clean the plastic and avoid adding dust in the glycerin and water mix in next step and then, modify its density.

The flotation separation in water is carried out as follows:

- Gradually and evenly introduce pieces of plastic on a single layer in the separator
- Wait 1-2 min
- collect the plastic sunk

The second stage consists in a flotation of the plastic which had sunk in the first step. The density of the flotation bath is fixed to 1,11, as the brominated plastics (with a bromine concentration higher than 1%¹) have a density higher than 1,11. The flotation separation is carried out with adapted equipment. A figure of a model of separator is presented in Annex 1. A liquid made of glycerin (d=1,26) and water (d=1) can be used to reach the proper density. The density shall be controlled.

The flotation separation in glycerin is carried out as follows:

- Weigh the sample to be analyzed (M_{samp})
- Gradually and evenly introduce pieces of plastic on a single layer in the separator
- Wait 1-2 min
- Collect separately plastics, heavy and light.

The heaviest pieces could contain non-brominated plastics, a second step is necessary to confirm the result.

Bromine analysis of each sunk piece

Analysis of each piece may be made on-site or in laboratory. In the case of laboratory analysis, condition heavy plastics by resin pieces. Containers should be clearly labeled, with the name of the site (or code), the categories of WEEE, the resin name and date of collection.

For the bromine analysis, one of the following analytical methods may be used: Fluorescence X / LIBS / Sliding Spark Spectrometer

Example: Setting up X-ray fluorescence unit:

- Choose the mode of analysis of plastics
- Calibrate with bromine
- Set the time of analysis to 10 sec.

To analyze heavy plastics, proceed as follows:

- Dry the pieces of plastics
- Analyze the pieces of plastic one by one. If the appearance of the plastic is different between both sides, do a scan per side.

If a piece has more than 3% of bromine, it is declared brominated. Below 3%, the piece is declared non-brominated.

Pieces with more than 3% of bromine are weighed (M_{plastB})

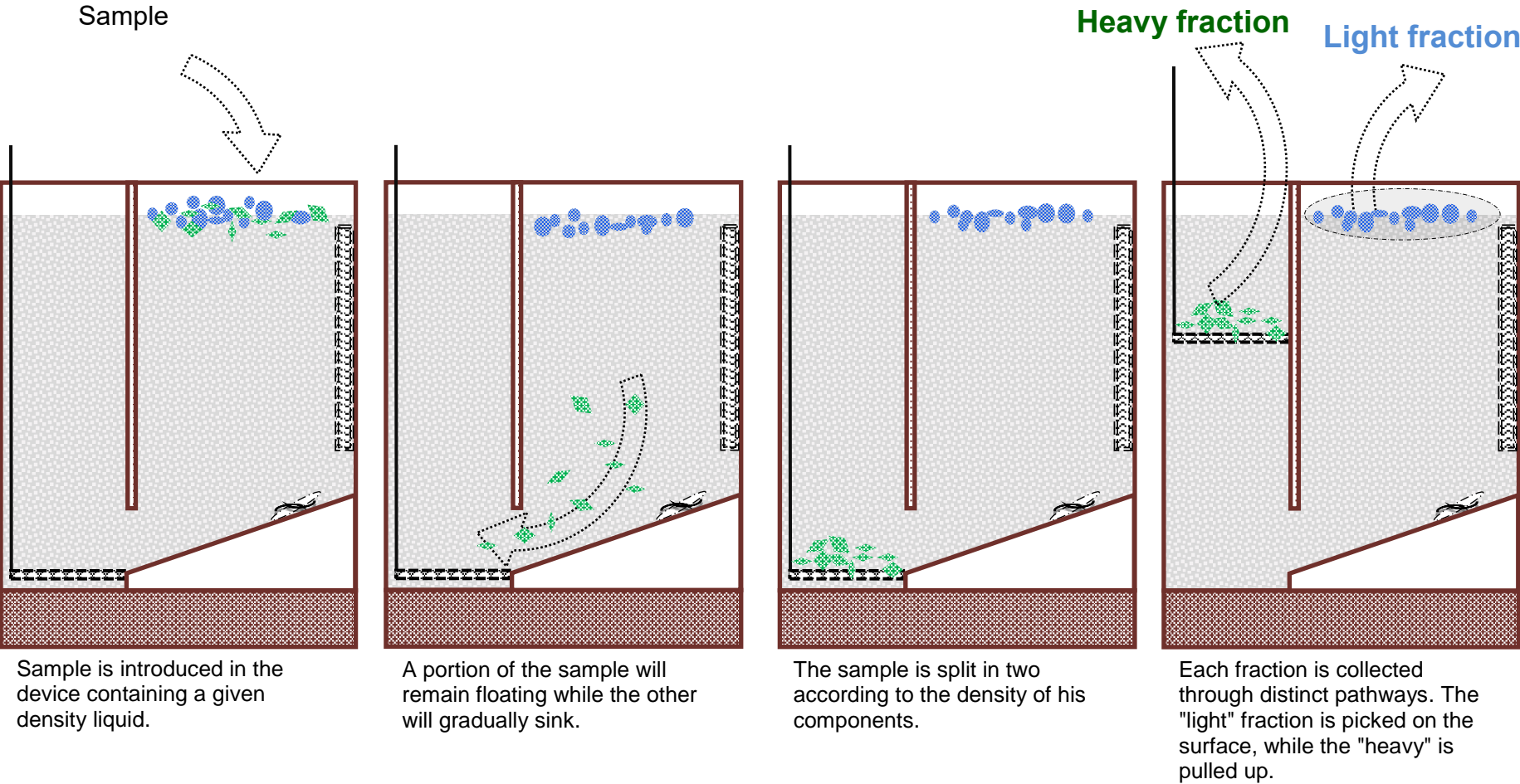
For each resin or mix, the result is calculated and compare to the limit value:

$$\% \text{ of brominated plastic} = M_{\text{plastB}} / M_{\text{samp}}$$

The result is compared to the limit value 1,2%.

Depollution rate is equal to $= 1 - (\text{Analysis result in the input} / \text{Analysis result in the output})$

Appendix 2: Schema of the portable flotation separation device



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Annex 1: Assessment of pollutants in input appliances

1. Approach 2: Investigation through batches on actual treatment results

1.1. Weighing protocol

1.1.1. General points

Weighing of input material and components removed during the batch must follow the requirements described in *WEEELABEX Standard on Treatment – Annex C: Requirements concerning batches*.

Input material may include sorting mistakes (ex: Screens in SHA Flow). When it is possible, the sorting mistakes should be taken out of the input material before running the batch, so that only products that belong to the normal flow remain as input material.

Only components removed from the processed incoming appliances must be accounted (and not be added up to components removed from other treatment flows or waste). Components must be weighed separately per type (capacitors, batteries, printed circuit boards).

The weighing equipment used should have sufficient accuracy and must be regularly checked. The weight of the recipient in which the components are gathered together for weighing must be deducted to the gross weight in order to obtain the net weight of components (net weight = gross weight – tare weight).

1.1.2. Details on the components before weighing

Capacitors

In order to be able to have comparable results, it is necessary to make sure that:

- only the kinds of capacitors in scope (see Annex 3) removed from the incoming flow will be weighed
- all removed capacitors will be cleared of cable and printed circuit boards' pieces before weighing
- capacitors will be weighed separately from any other kind of removed components (ex: batteries; an easy way to distinguish capacitors from batteries is to look if the component is marked with "µF" which is the capacity unit symbol, only present on capacitors)

Batteries

In order to be able to have comparable results, it is necessary to make sure that:

- all removed batteries will be cleared of printed circuit boards' and cable pieces before weighing
- batteries will be weighed separately from any other kind of removed components (ex: capacitors) from input appliance

Printed circuit boards

In order to be able have comparable results, it is necessary to make sure that:

- all printed circuit boards removed from the incoming flow will be weighed (see Annex 3)
- all removed batteries and capacitors in scope will be cleared of printed circuit boards' pieces before weighing

Note1: printed circuit boards can be removed at several steps in the treatment process. The quantity removed at each step must be weighed and registered for accounting.

Note2: In addition, samples of output fractions (fractions: capacitors, batteries, printed circuit boards) could be taken out once a year to determine what is the average quantity of out of scope components in the removed fractions (ex: too small capacitors, pieces of cables, etc.). Based on these measurements, a correction factor would be applied in the batches results to determine the real quantity of removed components in scope.

For instance:

- the quantity of capacitors removed during the batch is 240 kg
- the analysis of a sample of 10 kg shows that 1 kg (= 10% of 10 kg) are out of scope capacitors (volume < 12,27 cm³)
- after correction we obtain that the removed quantity of capacitors in scope is 90% of 240 kg = 216 kg; we replace it in the batches results

1.2. Procedure

This approach consists in:

- gathering de-pollution results obtained by treatment plants through treatment batches
- analysing them statistically in order to fix the objectives of pollutants to be removed

1.2.1. Batches measurements and data

The following requirements must be satisfied:

- To conduct treatment batches and on all treatment plants at least every two years in order to get enough representative de-pollution results
- To follow the batches procedure described in WEEELABEX-Standard on Treatment
- To respect the weighing protocols described previously in 1.1.
- In the particular case of treatment of 2 different flows together (ex: LHA, Large Household Appliances and SHA, Small Household Appliances) on the same plant at the same time, the quantities of input material of each flow have to be weighed and registered carefully before treatment (in order to have the possibility through approach 4 to calculate the objective value of components to be removed in this particular case, by crossing the objective value per flow obtained through approach 4 with the weight percentage of each input flow on the plant)

1.2.2. Data analysing and model calculation

Once previous conditions are fulfilled, data can be analysed in order to calculate the limit values.

The idea is to update the limit values each year for each treatment flow, based on de-pollution results of the year. Results of past year must also be taken into account when data have been measured according to requirements in 1.2.1.

Model calculation:

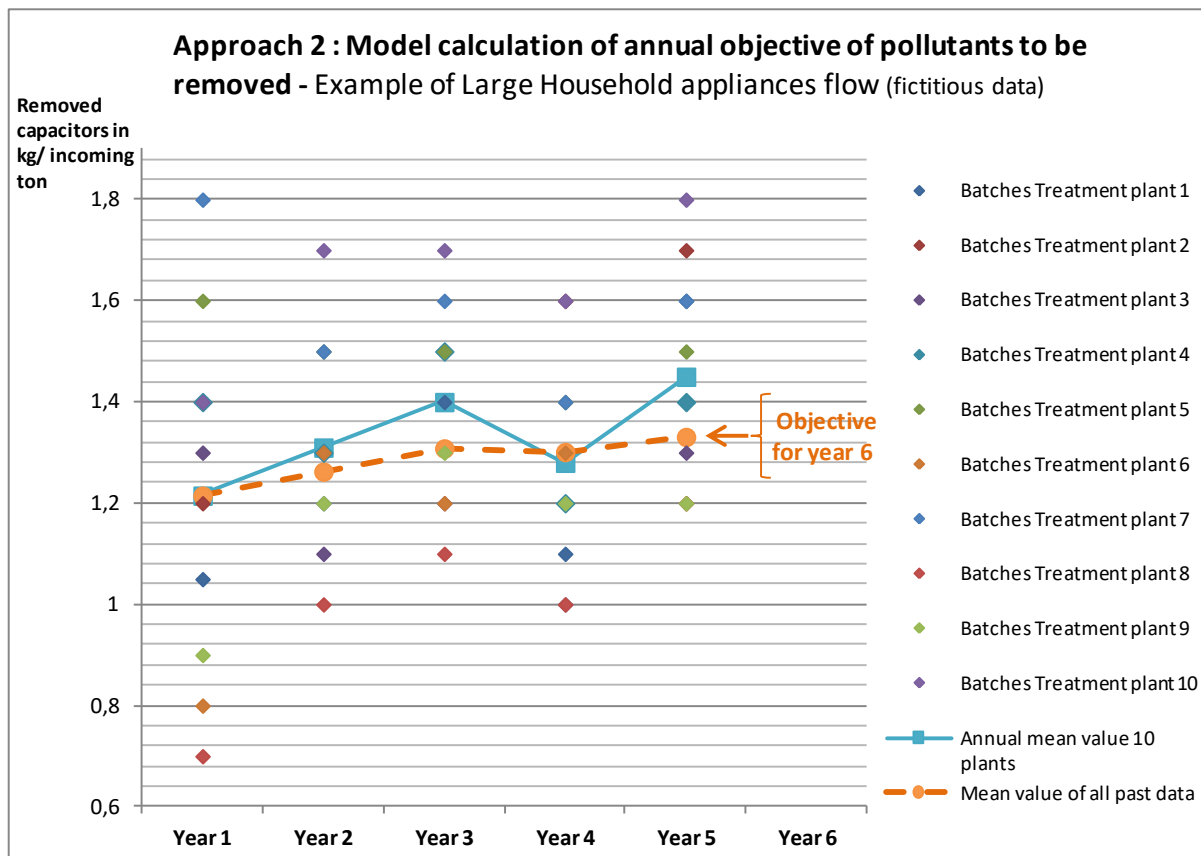
- We consider for a given treatment flow and a given component (ex: capacitors) :
 - q_{pi} = quantity of components per incoming ton (kg/ton) measured during a batch in year i on a treatment plant p
 - n = number of treatment plants (in a country for example)
 - m_i = mean value in year i of q_{pi} , with p : 1 to n

$$m_i = \frac{\sum_{p=1}^n q_{pi}}{n}$$

- We calculate each year y the actualized mean value M of quantity of pollutants removed by all treatment plants (since the beginning year 1), that will constitute the objective for the following year $y+1$:
 - M_y = mean value of all past data q_{pi}

$$M_y = \frac{\sum_{i=1}^y m_i}{y}$$

We illustrate this model calculation on the graph below (based on fictitious batches data).



We read on this graph that the objective of quantity of capacitors to be removed in year 6 would be 1.33 kg per incoming ton of LHA.

Remark on this model calculation: By fixing the limit value for the following year, a tolerance factor could be applied in addition, based on the variability of the data. This could be calculated as the lower bound of the confidence interval around the mean objective as follows:

$$\text{Lower bound confidence interval}^{(1)} = M_y - \sigma$$

With: σ = standard deviation of all past data

(1) Calculation formula of confidence interval lower bound, in case of chronological series – stationary process MA(1)

When applied to our fictitious data above, we obtain:

$$\text{Lower bound confidence interval} = 1.33 - 0.25 = \text{limit value of } 1.08 \text{ kg/t}$$

2. Approach 3: Statistical input analyses of incoming flow

2.1. Weighing protocol

The components removed in this approach will be collected in receptacles for weighing (one receptacle for capacitors, one for batteries, one for printed circuit boards). The components (ex: capacitors) removed from the appliances coming from one delivery's container will be collected in the same receptacle for weighing.

The weighing equipment used to weigh the receptacle should be appropriate and have sufficient accuracy (depending of the quantity and weight of components inside). The net weight of the receptacle has to be determined (net weight = gross weight – tare weight).

The number of components in the receptacle could be also collected (see *Annex 5: Approach 3 - Standard collection data sheet for components in scope*).

Once the receptacle has been weighed (net weight), the components inside can be stored in a storage container, in order to make the receptacle free for the collection of the components that will be removed from the appliances of the next delivery's container.

2.1.1. Capacitors

In order to be able to have comparable results, it is necessary to make sure that:

- only the kinds of capacitors in scope (see Annex 3) will be removed from the appliances
- all removed capacitors will be cleared of cable and printed circuit boards' pieces
- capacitors will be separated from any other kind of removed components (ex: batteries; an easy way to distinguish capacitors from batteries is to look if the component is marked with "µF" which is the capacity unit symbol, only present on capacitors)

2.1.2. Batteries

In order to be able to have comparable results, it is necessary to make sure that:

- only the batteries in scope (see Annex 3) will be removed from the appliances
- all removed batteries will be cleared of printed circuit boards' pieces
- batteries will be separated from any other kind of removed components (ex: capacitors) from input appliance

2.1.3. Printed circuit boards

In order to be able to have comparable results, it is necessary to make sure that:

- all printed circuit boards removed from the incoming appliances will be weighed (see Annex 3)
- all removed batteries and capacitors in scope will be cleared of printed circuit boards' pieces before weighing

2.2. Procedure

This approach consists in

- Measuring the quantities of components in input appliances that constitute the incoming flow
- analysing statistically the results in order to fix the objectives of pollutants to be removed

2.2.1. General principle

We consider deliveries of incoming flow that are normally intended to be processed in recycling plants.

The general principle is:

- to take out samples of deliveries (x deliveries of containers of incoming flow),
- to measure their content in components (capacitors, batteries, printed circuit boards),

- to calculate the mean value of quantity of components per incoming ton, based on the measurements results

This approach (as approach 4) involves extracting the components from the appliances that constitute the incoming flow.

2.2.2. Measurements and collection of data

The main data we need to collect are following (per treatment flow):

- Weight of incoming appliances that will be analysed
- Weight of components that are removed from the appliances

In order to assess the uncertainty margins of the results and variability, we need to do measurements for each delivery or each container of incoming appliances.

2.2.2.1. Collection of data 1: Weight and quantity of incoming appliances

The net weight of each container of appliances has to be determined as follows:

Net weight container = gross weight – tare weight

The weighing equipment used should have sufficient accuracy³ and must be regularly checked. The weight of the container must be deducted to the gross weight in order to obtain the net weight of appliances.

Then, once the container unloaded, the appliances will be taken one by one in order to remove the components inside. Additional information to collect would be the total number of appliances in the container.

To sum up the data to be collected:

- Net weight by container
- Number of appliances by container

2.2.2.2. Collection of data 2: measurement of the quantity of components in the appliances

The components in the scope ⁽¹⁾ of WLX-Benchmarks are: **capacitors, batteries and printed circuit boards.**

(1) Option: each country / WEEE-system is free to add to its own scope of pollution assessment other components listed in annex II of 2002/96/CE directive.

These components should be searched and removed from each appliance. The most appropriate mean to extract them without damaging is manual dismantling (with appropriate dismantling tools: screwdriver, pliers, hammer...).

We need to get for each container of appliances the following data on components:

- Kind of removed component,
- Weight,
- Number of units

We give below some more details on the characteristics of components in scope and their weighing protocols.

Details on components in scope:

³ for example: at least 0.5 kg accuracy for 1 up to 2 m3 containers, at least 20 kg accuracy for 30 m3 containers or trucks deliveries

2.2.2.3. Capacitors:

All capacitors mentioned in annex II of 2002/96/CE directive should be removed from the input appliances:

- Electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm, or proportionately similar volume): these capacitors are polarized, marked “+” and “-“conductors and can be mainly found on printed circuit boards. Only marked “+” and/or “-“capacitors with height> 25 mm, diameter> 25 mm, or proportionately similar volume i.e. > 12,272 cm³ should be removed. We join in annex 3 a list (of all couples of min. values height-diameter which give a volume > 12,272 cm³) that could be used to decide if the electrolyte capacitor is in scope or not.
- Polychlorinated biphenyls (PCB) containing capacitors: these capacitors are not polarized (not marked “+” and/or “-“) and have theoretically no size restriction. All capacitors which may not be identified as PCB free⁴ shall be considered as PCB containing or PCB suspect capacitors and should be removed.

The capacitors need to be removed unharmed from the input appliances.

2.2.2.4. Batteries:

“WLX-Annex A De-pollution guidelines” makes the distinction between **external batteries** which “have to be removed” as a first step of the treatment process and **internal batteries** which “have to/(could) be removed “as an identifiable (part of a) stream in the next steps of the treatment process.

Therefore, in order to better compare limit values with de-pollution results, separate weighing and data collection of external batteries and internal batteries could be recommended after having removed these components from input appliances (see *annex 5 Approach 3 – Standard collection data sheet for components in scope*).

Scope of batteries: all kind of batteries and accumulators (see WEEELABEX A4).

2.2.2.5. Printed circuit boards:

All printed circuit boards whose surface is greater than 10 square centimetres are in scope (see Annex II of 2002/96/CE directive; WEEELABEX A5) and should be removed for weighing. In praxis, shredding treatment processes cannot separate printed circuit boards whose surface is greater than 10 cm² from other circuit boards. Consequently we propose to remove and weigh all printed circuit boards from input appliances.

Note: It could be interesting for the results to distinguish the 2 size of printed circuit boards by the collecting of data (> 10 cm² and ≤ 10 cm² see Annex 5 Approach 3 – Standard collection data sheet for components in scope).

⁴ WLX A2.2: Capacitors can only be considered as PCB free, if one of the following criteria is fulfilled:

- if they have been produced after 1986 or they come from appliances produced after 1987
- if they are declared and labelled as PCB free
- if they are declared as PCB free by documents of the producing company
- if conductors are polarized and marked “+” or/and “-“ (electrolyte capacitors)

Note: Investigations by Fundacion Ecolec have led to the conclusion that capacitors with plastic mantle or casing do not contain PCB. In case of decision of not removing these capacitors from WEEE appliances during treatment, the objective and limit values for capacitors should be different in this case. We could imagine that specific limit values could be set up for this particular case. These would be different to limit values set up by other systems that still remove plastic casing capacitors.

2.2.3. Data analysing and model calculation

Once previous conditions are fulfilled, data can be analysed in order to calculate the limit values.

Model calculation:

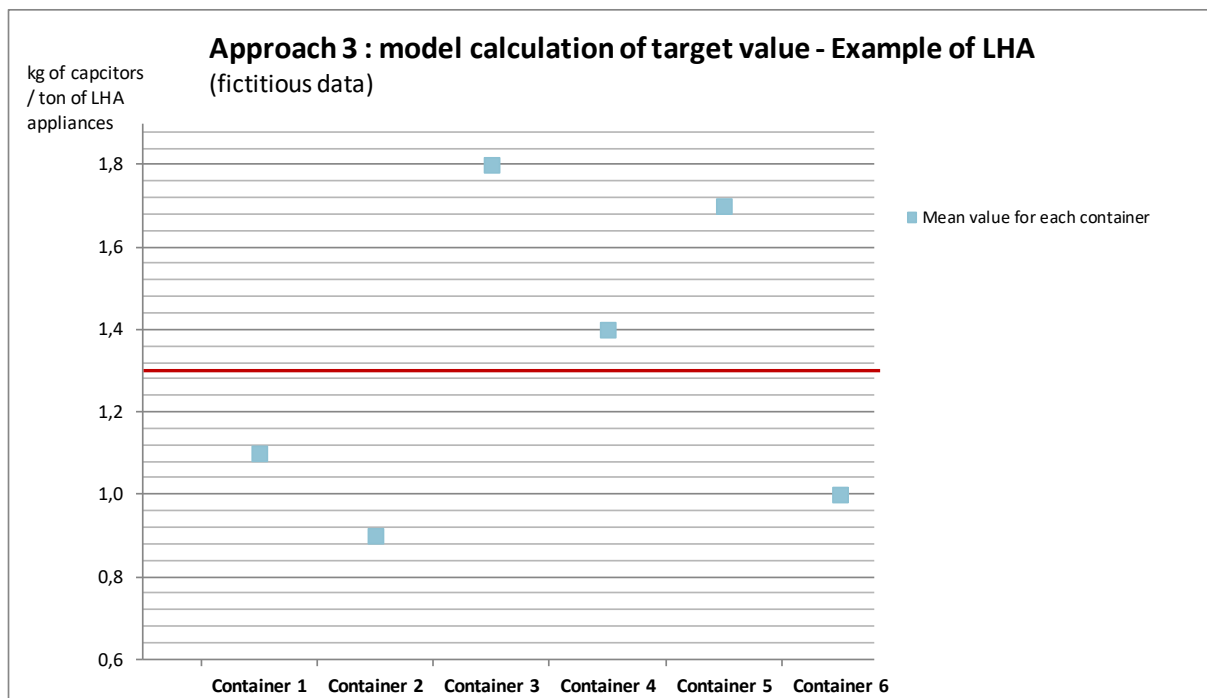
- We consider for a given treatment flow and a given component (ex: capacitors) :
 - w_i = net weight (tons) of delivery's container i
 - q_i = total quantity of components (kg) removed from all appliances of container i
 - m_i = mean value of components removed from appliances of container i

$$m_i = \frac{q_i}{w_i}$$

- We calculate the mean value M_y of components removed from the incoming appliances of all containers that have been analysed (with y: the total number of delivery's containers)

$$M_y = \frac{\sum_{i=1}^y m_i}{y}$$

We illustrate this model calculation on the graph below (based on fictitious data).



We read on this graph that the objective of quantity of capacitors to be removed (based on the measurements on 6 containers of LHA) would be 1.3 kg per incoming ton of LHA.

Remark on this model calculation: By fixing the limit value, a tolerance factor could be applied, based on the variability of the data. This could be calculated as the lower bound of the confidence interval around the mean objective as follows:

$$\text{Lower bound confidence interval} = M_y - q(1-\alpha) \sigma/\sqrt{n}$$

With:

α : confidence level

q : quantile of the standard normal distribution

σ : standard deviation of the data

n : number of data

When applied to our fictitious data above (with 95% confidence level), we obtain:

Lower bound confidence interval = $1.3 - 0.3 =$ limit value of 1.0 kg/t

3. Approach 4: Statistical input analyses detailed by categories and/or type of appliance

Preliminary observations:

The treatment flows are composed of mixtures of input categories/products which can be different from one country to another.

Due in particular to different sorting instructions on collection facilities and different acceptance rules for sorting mistakes on treatment facilities for a “same” treatment flow, the kinds of products within a treatment flow could be quite different from one country to another. For example: sorting instructions are different for microwave ovens (category 1) from one WEEE-system to another (SHA or LHA flow).

The proposed method is to measure the quantities of polluting components in input appliances (per category or type of product) that involves extracting the components from each appliance one by one.

3.1. Weighing protocol

3.1.1. Capacitors

In order to be able to have comparable results, it is necessary to make sure that:

- only the kinds of capacitors in scope (see Annex 3) will be removed from the appliances and weighed
- all removed capacitors will be cleared of cable and printed circuit boards' pieces before weighing
- capacitors will be weighed separately from any other kind of removed components (ex: batteries; an easy way to distinguish capacitors from batteries is to look if the component is marked with “ μ F” which is the capacity unit symbol, only present on capacitors)

Appropriate weighing equipment should be used with sufficient accuracy (for example: of the order of 0,5g up to 1g accuracy; to be able to weigh one capacitor if only one is found and removed from an input appliance).

3.1.2. Batteries

In order to be able to have comparable results, it is necessary to make sure that:

- only the batteries in scope (see Annex 3) will be removed from the appliances and weighed
- all removed batteries will be cleared of printed circuit boards' pieces before weighing
- batteries will be weighed separately from any other kind of removed components (ex: capacitors) from input appliance

Appropriate weighing equipment should be used with sufficient accuracy (for example: of the order of 0,5g up to 1g accuracy; to be able to weigh one battery if only one is found and removed from an input appliance).

3.1.3. Printed circuit boards

In order to be able have comparable results, it is necessary to make sure that:

- all printed circuit boards removed from the incoming appliances will be weighed (see Annex 3)
- all removed batteries and capacitors in scope will be cleared of printed circuit boards' pieces before weighing

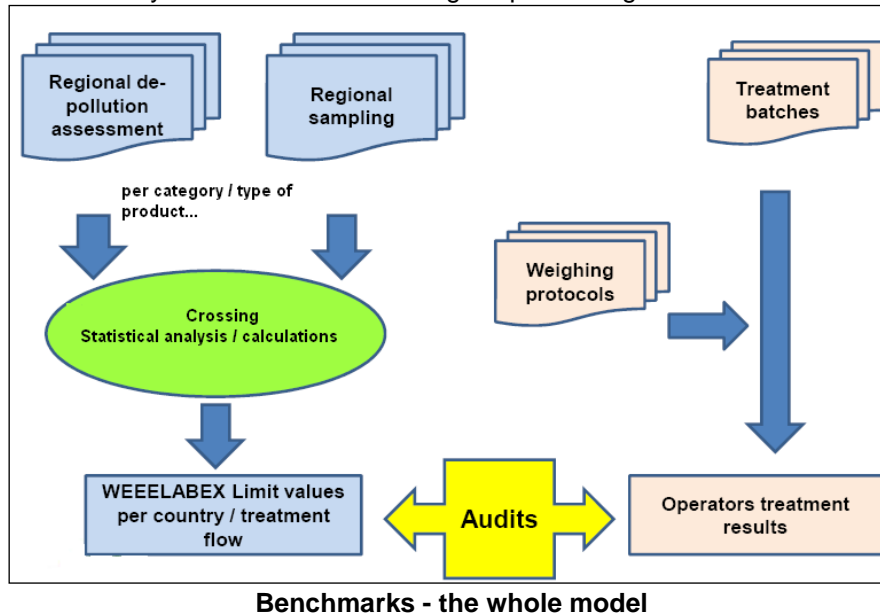
Appropriate weighing equipment should be used with sufficient accuracy (for example: of the order of 0,5g up to 1g accuracy; to be able to weigh one battery if only one is found and removed from an input appliance).

3.2. Procedure

This method consists in⁵:

- assessment or measurement of the pollution content in appliances (for each type of product or category) that constitute the incoming treatment flows,
- calculation of the limit values per treatment flow⁶ by crossing pollution assessment results (per type of product or category) with sampling results (composition in products/categories of each treatment flow)

This whole model is synthesized in the following simplified diagram:



⁵ at a regional level: country

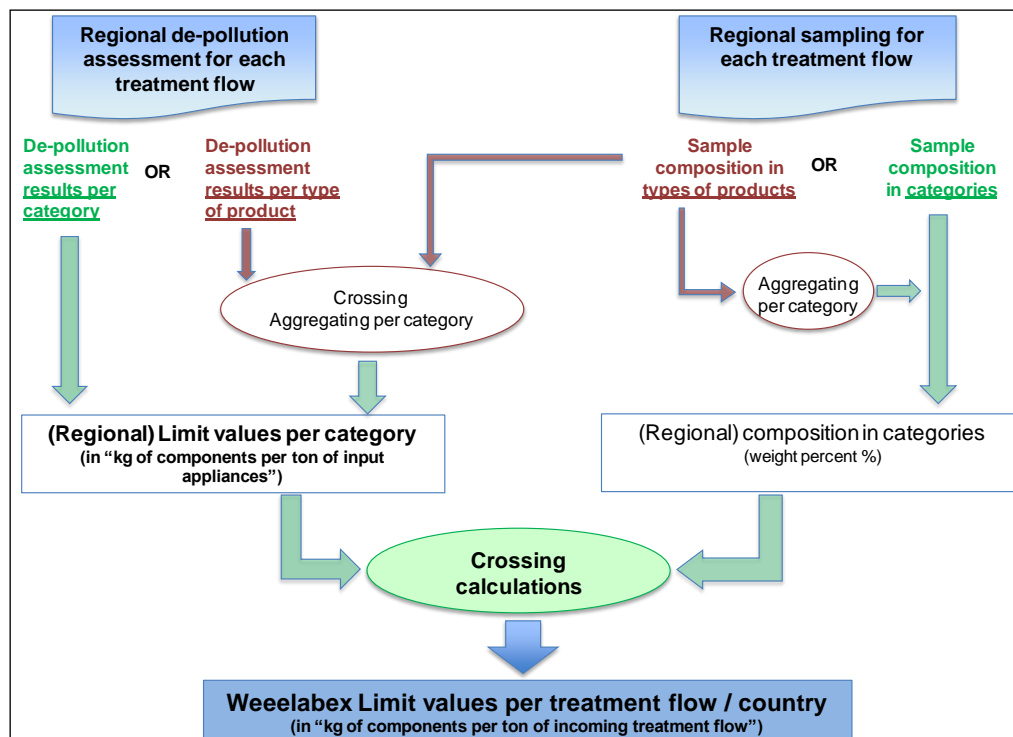
⁶ Reminder: the treatment flow is the incoming stream in the treatment facility (SHA, LHA, screens, C&F Appliances...)

3.2.1. Collection of data 1: Category data / type of product

Before extracting components from each appliance, we propose to collect not only the appliance's category data but also which kind of product it is according to a common product list⁷ (cf. Annex 2). It would enable to compare the pollution content values using a same basis (product level) between the different countries and help to set up limit values at a European level.

Aggregating calculations would then enable to determine limit values per category. If the kind of product data is not collected, the category data should at least be collected.

The following diagram synthesizes the model calculation in both cases (pollution assessment results per type of product according to a common products list or per category only):



Benchmarks – Model calculation for the setting up of limit values per treatment flow / country

3.2.2. Collection of data 2: Weight of input appliances

In addition to the data “kind of product”/“category”, we need to weigh each appliance in order to be able to calculate the ratio:

“Quantity of components per kg (or ton) of input appliances”.

The integrity of the appliance (“complete” or “not”) could be also collected as additional data.

To sum up, the following data would be collected for each input appliance:

- Treatment flow
- Type of product (simplified products list) / category data
- Weight⁸
- Additional data: complete or not

⁷ A simplified products list is joined in annex 2 (with cross-reference to categories and treatment flows' possibilities) that could be used and completed by each country/WEEE-system (with a centralized management by the WEEE Forum)

⁸ Appropriate weighing equipment should be used with sufficient accuracy (for example: at least 500g accuracy for large household appliances and 50g accuracy for small household appliances)

3.2.3. Collection of data 3: measurement of the quantity of components in the appliances

The components in the scope ⁽¹⁾ of WEEELABEX Benchmarks are: **capacitors, batteries and printed circuit boards.**

(1) Option: each country / WEEE-system is free to add to its own scope of pollution assessment other components listed in annex II of 2002/96/CE directive.

These components should be searched and removed from each input appliance. The most appropriate mean to extract them without damaging is manual dismantling (with appropriate dismantling tools: screwdriver, pliers, hammer...).

The components' data we need to get for each input appliance are basically:

- kind of removed component,
- weight,
- number of units

We give below some more details on the characteristics of components in scope and their weighing protocols.

Details on components in scope:

3.2.3.1. Capacitors:

All capacitors mentioned in annex II of 2002/96/CE directive should be removed from the input appliances:

- Electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm, or proportionately similar volume): these capacitors are polarized, marked "+" and "-" conductors and can be mainly found on printed circuit boards. Only marked "+" and/or "-" capacitors with height > 25 mm, diameter > 25 mm, or proportionately similar volume i.e. > 12,272 cm³ should be removed. We join in annex 3 a list (of all couples of min. values height-diameter which give a volume > 12,272 cm³) that could be used to decide if the electrolyte capacitor is in scope or not.
- Polychlorinated biphenyls (PCB) containing capacitors: these capacitors are not polarized (not marked "+" and/or "-") and have theoretically no size restriction. All capacitors which may not be identified as PCB free⁹ shall be considered as PCB containing or PCB suspect capacitors and should be removed.

The capacitors need to be removed unharmed from the input appliances.

Note: It could be interesting for the results to distinguish these 2 kinds of capacitors by the collecting of data (see *proposed collection data sheet in Annex 6*)

3.2.3.2. Batteries:

"WEEELABEX Annex A De-pollution guidelines" makes the distinction between **external batteries** which "have to be removed" as a first step of the treatment process and **internal batteries** which "have to/(could) be removed "as an identifiable (part of a) stream in the next steps of the treatment process.

⁹ WLX A2.2: Capacitors can only be considered as PCB free, if one of the following criteria is fulfilled:

- if they have been produced after 1986 or they come from appliances produced after 1987
- if they are declared and labelled as PCB free
- if they are declared as PCB free by documents of the producing company
- if conductors are polarized and marked "+" or/and "-" (electrolyte capacitors)

Note: Investigations by Fundacion Ecolec have lead to the conclusion that capacitors with plastic mantle or casing do not contain PCB. In case of decision of not removing these capacitors from WEEE appliances during treatment, the objective and limit values for capacitors should be different in this case. We could imagine that specific limit values could be set up for this particular case. These would be different to limit values set up by other systems that still remove plastic casing capacitors.

Therefore, in order to better compare limit values with de-pollution results, separate weighing and data collection of external batteries and internal batteries could be recommended after having removed these components from input appliances (see *Annex 5: Approach 3 - Standard collection data sheet for components in scope*).

Scope of batteries: all kind of batteries and accumulators (see WEEELABEX A4).

3.2.3.3. Printed circuit boards:

All printed circuit boards whose surface is greater than 10 square centimetres are in scope (see Annex II of 2002/96/CE directive; WEEELABEX A5) and should be removed for weighing. In praxis, shredding treatment processes cannot separate printed circuit boards whose surface is greater than 10 cm² from other circuit boards. Consequently we propose to remove and weigh all printed circuit boards from input appliances.

Note: It could be interesting for the results to distinguish the 2 size of printed circuit boards by the collecting of data (> 10 cm² and ≤ 10 cm² see *Annex 5: Approach 3 - Standard collection data sheet for components in scope*)

3.2.4. Data analysing and model calculation

Once previous conditions are fulfilled, data can be analysed in order to calculate the limit values.

a) Approach per type of product

- First step: Calculation of pollution assessment results for each product

Following calculation has to be done for each product based on the measurements carried out on input appliances:

Average rate of ComponentA for product 1 (in kg of ComponentA per ton of input appliances) = **total weight of ComponentA removed from product1 (in kg) / total weight of product1 in tons** (before removing components)

→ Example for capacitors removed from washing machines:

Capacitors average rate for washing machine (kg of capacitors / t of appliances) = **Total weight of capacitors removed from washing machines / total weight of washing machines**

- Second step: to cross the pollution assessment results with sampling results of incoming flows

The table below illustrates the cross calculation that has to be done (based on fictitious data for LHA Flow and capacitors).

Products of LHA Flow	(weight) composition of LHA Flow (sampling results ¹)		Products pollution assessment results (capacitors average rate ¹)	Calculation results for LHA Flow (capacitors average rate)
Washing machine	51%	x	1,6 kg/t of appliances	= 0,8 kg/t of LHA
Dishwasher	15%	x	1,3 kg/t of appliances	= 0,2 kg/t of LHA
Cooker	11%	x	0,0 kg/t of appliances	= 0,0 kg/t of LHA
Water heater	6%	x	0,0 kg/t of appliances	= 0,0 kg/t of LHA
Built-in Oven	5%	x	0,4 kg/t of appliances	= 0,0 kg/t of LHA
Tumble-dryer	4%	x	1,7 kg/t of appliances	= 0,1 kg/t of LHA
Microwave oven	2%	x	10,5 kg/t of appliances	= 0,2 kg/t of LHA
...
TOTAL LHA Flow	100%			1,3 kg/t of LHA

Sum Σ = 1,3 kg/t of LHA

¹ Fictitious data

Model calculation of the objective of pollutants to be removed (example of LHA – capacitors)

We read in this example that the objective of quantity of capacitors to be removed would be 1.3 kg per incoming ton of LHA.

Remark on this model calculation: By fixing the limit value, a tolerance factor could be applied in addition, based on the uncertainty of the data. This could be calculated as the lower bound of the confidence interval around the mean objective as follows:

- First, calculation of the lower bound value for each kind of product, based on the data:

Kind of product constituting of the incoming flow	Mean value (average rate of capacitors in kg/t)	Lower bound value of confidence interval (lb in kg/t)
Product 1	m_1 kg/t of appliances	$lb_1 = m_1 - q(1-\alpha) \sigma/\sqrt{n_1}$
Product 2	m_2 kg/t of appliances	$lb_2 = m_2 - q(1-\alpha) \sigma/\sqrt{n_2}$
Product 3	m_3 kg/t of appliances	$lb_3 = m_3 - q(1-\alpha) \sigma/\sqrt{n_3}$
Product 4	m_4 kg/t of appliances	$lb_4 = m_4 - q(1-\alpha) \sigma/\sqrt{n_4}$
...

With:

α : confidence level

q : quantile of the standard normal distribution

σ : standard deviation of the data

n : number of data (number of appliances that have been analyzed)

- Secondly, crossing of lower bound values for each product with sampling results of the incoming flow (example below with LHA Flow – capacitors; fictitious data)

Products of LHA Flow	(weight) composition of LHA Flow (sampling results ¹)		Lower bound value (lb) for removed capacitors ¹	Calculation results for LHA Flow (capacitors lower bound value)
Washing machine	51%	x	1,4 kg/t of appliances	= 0,7 kg/t of LHA
Dishwasher	15%	x	1,1 kg/t of appliances	= 0,2 kg/t of LHA
Cooker	11%	x	0,0 kg/t of appliances	= 0,0 kg/t of LHA
Water heater	6%	x	0,0 kg/t of appliances	= 0,0 kg/t of LHA
Built-in Oven	5%	x	0,3 kg/t of appliances	= 0,0 kg/t of LHA
Tumble-dryer	4%	x	1,6 kg/t of appliances	= 0,1 kg/t of LHA
Microwave oven	2%	x	9,5 kg/t of appliances	= 0,2 kg/t of LHA
...
TOTAL LHA Flow	100%			1,1 kg/t of LHA ← Sum Σ =

¹ Fictitious data

Model calculation of the lower bound value of objective of pollutants to be removed (example of LHA – capacitors)

We read on the table above that the limit value becomes 1.1 kg/ton (lower “tolerance limit”).

b) Approach per category

- First step: Calculation of pollution assessment results for each category

Following calculation has to be done for each category based on the measurements carried out on input appliances:

Average rate of ComponentA for category (in kg of ComponentA per ton of input appliances) = **total weight of ComponentA removed from category (in kg) / total weight of category in tons** (before removing components)

→ Example for capacitors removed from category 6. Electrical and electronic tools:

Capacitors average rate for category 6 (kg of capacitors / t of appliances) = **Total weight of capacitors removed from category 6 / total weight of category 6**

- Second step: to cross the pollution assessment results with sampling results of incoming flows

The table below illustrates the cross calculation that has to be done (based on fictitious data for SHA Flow and capacitors).

Categories of SHA Flow	(weight) composition of SHA Flow (sampling results ¹)		Categories pollution assessment results (capacitors average rate ¹)	Calculation results for SHA Flow (capacitors average rate)	
Category 1	9%	x	1,8 kg/t of appliances	= 0,2 kg/t of SHA	Sum Σ =
Category 2	28%	x	0,9 kg/t of appliances	= 0,3 kg/t of SHA	
Category 3	26%	x	1,5 kg/t of appliances	= 0,4 kg/t of SHA	
Category 4	24%	x	1,2 kg/t of appliances	= 0,3 kg/t of SHA	
Category 6	3%	x	0,4 kg/t of appliances	= 0,0 kg/t of SHA	
Category 7	4%	x	0,3 kg/t of appliances	= 0,0 kg/t of SHA	
Category 8	1%	x	0,5 kg/t of appliances	= 0,0 kg/t of SHA	
Category 9	5%		0,9 kg/t of appliances	= 0,0 kg/t of SHA	
TOTAL SHA Flow	100%			1,2 kg/t of SHA	←

¹ Fictitious data

Model calculation of the objective of pollutants to be removed (example of SHA – capacitors)

We read in this example that the objective of quantity of capacitors to be removed would be 1.2 kg per incoming ton of SHA.

Remark on this model calculation: By fixing the limit value, a tolerance factor could be applied in addition, based on the uncertainty of the data. This could be calculated as the lower bound of the confidence interval around the mean objective as follows:

- First, calculation of the lower bound value for each category, based on the data:

Kind of category constituting of the incoming flow	Mean value (average rate of capacitors in kg/t)	Lower bound value of confidence interval (lb in kg/t)
Category 1	m_1 kg/t of appliances	$lb_1 = m_1 - q(1-\alpha) \sigma/\sqrt{n_1}$
Category 2	m_2 kg/t of appliances	$lb_2 = m_2 - q(1-\alpha) \sigma/\sqrt{n_2}$
Category 3	m_3 kg/t of appliances	$lb_3 = m_3 - q(1-\alpha) \sigma/\sqrt{n_3}$
Category 4	m_4 kg/t of appliances	$lb_4 = m_4 - q(1-\alpha) \sigma/\sqrt{n_4}$
...

With:

α : confidence level

q : quantile of the standard normal distribution

σ : standard deviation of the data

n : number of data (number of appliances that have been analyzed)

- Secondly, crossing of lower bound values for each category with sampling results of the incoming flow (example below with SHA Flow – capacitors; fictitious data)

Categories of SHA Flow	(weight) composition of SHA Flow (sampling results ¹)		Lower bound value (lb) for removed capacitors ¹	Calculation results for SHA Flow (capacitors lower bound value)
Category 1	9%	x	1,6 kg/t of appliances	= 0,1 kg/t of SHA
Category 2	28%	x	0,7 kg/t of appliances	= 0,2 kg/t of SHA
Category 3	26%	x	1,3 kg/t of appliances	= 0,3 kg/t of SHA
Category 4	24%	x	1,0 kg/t of appliances	= 0,2 kg/t of SHA
Category 6	3%	x	0,3 kg/t of appliances	= 0,0 kg/t of SHA
Category 7	4%	x	0,2 kg/t of appliances	= 0,0 kg/t of SHA
Category 8	1%	x	0,3 kg/t of appliances	= 0,0 kg/t of SHA
Category 9	5%		0,7 kg/t of appliances	= 0,0 kg/t of SHA
TOTAL SHA Flow	100%			1,0 kg/t of SHA

Sum Σ = ---

¹ Fictitious data

Model calculation of the lower bound value of objective of pollutants to be removed (example of SHA – capacitors)

We read on the table above that the limit value becomes 1.0 kg/ton (lower “tolerance limit”).

Toolkit for the assessment of the input pollutants

The assessment of the pollutants included in the input flow has to be done following common rules that are explained in 3.1. In this goal tools were developed in order to uniform collection of those data. These tools are gathered in a separated document named “**Toolkit for pollutant input assessment**”, a document developed by WEEELABEX.

Annex 2: Simplified products list

Product code	Product name	WEEE category (2002/96/CE)	Treatment flow possibilities
1	Air conditioner	Category 1	C&F Appliances
2	Chest Freezer	Category 1	C&F Appliances
3	Refrigerator	Category 1	C&F Appliances
4	Upright freezer	Category 1	C&F Appliances
5	Wine cellar	Category 1	C&F Appliances
6	Beer machine (with refrigerant)	Category 1	C&F Appliances, SHA
7	Dishwasher	Category 1	LHA
8	Dryer	Category 1	LHA
9	Electrical Stove	Category 1	LHA
10	Washing machine	Category 1	LHA
11	Cooker Board	Category 1	LHA, SHA
12	Electric blanket	Category 1	LHA, SHA
13	Electric fan	Category 1	LHA, SHA
14	Electric Hob	Category 1	LHA, SHA
15	Extractor Hood	Category 1	LHA, SHA
16	Gaz/kerosene stove	Category 1	LHA, SHA
17	Gaz/Oil boiler	Category 1	LHA, SHA
18	Hot water tank	Category 1	LHA, SHA
19	Mechanical Ventilation system	Category 1	LHA, SHA
20	Microwave oven	Category 1	LHA, SHA
21	Mobile/fixed heater	Category 1	LHA, SHA
22	Oil Heater	Category 1	LHA, SHA
23	Towel dryer	Category 1	LHA, SHA
24	Animal food Dispenser	Category 2	SHA
25	Baby bottle heating device	Category 2	SHA
26	Balneotherapy set	Category 2	SHA
27	Bathroom scale	Category 2	SHA
28	Beer machine	Category 2	SHA
29	Blender	Category 2	SHA
30	Bread oven	Category 2	SHA
31	Breast pump	Category 2	SHA
32	Car Hand stick cleaner	Category 2	SHA
33	Chocolate maker	Category 2	SHA
34	Citrus press	Category 2	SHA
35	clock/ alarm clock	Category 2	SHA
36	Coffee grinder	Category 2	SHA
37	Coffee maker	Category 2	SHA
38	Combined electric toothbrush	Category 2	SHA
39	Curling iron	Category 2	SHA
40	Deep fryer	Category 2	SHA
41	Dish/Plate warmer	Category 2	SHA
42	Eggs beater	Category 2	SHA
43	Electric can opener	Category 2	SHA
44	Electric epilator	Category 2	SHA
45	Electric grinder	Category 2	SHA
46	Electric insect killer	Category 2	SHA
47	Electric knife	Category 2	SHA
48	Electric mincer	Category 2	SHA
49	Electric razor	Category 2	SHA
50	Electric tea machine	Category 2	SHA

Product code	Product name	WEEE category (2002/96/CE)	Treatment flow possibilities
51	Electric thermometer (no medical)	Category 2	SHA
52	Electric Toothbrush	Category 2	SHA
53	Electrolysis set	Category 2	SHA
54	Electronic trash can with sensitive cell	Category 2	SHA
55	Electrostimulation device	Category 2	SHA
56	Espresso-Systems	Category 2	SHA
57	Facial sauna	Category 2	SHA
58	Facial styling set	Category 2	SHA
59	Fan brush	Category 2	SHA
60	Floor polisher	Category 2	SHA
61	Fondue set	Category 2	SHA
62	Food slicer	Category 2	SHA
63	Foodprocessor	Category 2	SHA
64	Hair dryer	Category 2	SHA
65	Hair styling set	Category 2	SHA
66	Hair trimmer	Category 2	SHA
67	Hand dryer	Category 2	SHA
68	Hand stick cleaner	Category 2	SHA
69	Hot dog device	Category 2	SHA
70	Ice cream maker	Category 2	SHA
71	Ice maker without refrigerant	Category 2	SHA
72	Immersion heater	Category 2	SHA
73	Infrared lamp	Category 2	SHA
74	Iron	Category 2	SHA
75	Juice extractor	Category 2	SHA
76	Kettle	Category 2	SHA
77	Kitchen scale	Category 2	SHA
78	Knife sharpener	Category 2	SHA
79	Light Therapy set	Category 2	SHA
80	Luminous mirror	Category 2	SHA
81	Vaccum appliance for food	Category 2	SHA
82	Manicure and chiropodist set	Category 2	SHA
83	Massage device	Category 2	SHA
84	Meat grill	Category 2	SHA
85	Mini-oven	Category 2	SHA
86	Miniwasher	Category 2	SHA
87	pancakedevice	Category 2	SHA
88	Popcorn device	Category 2	SHA
89	Raclette set	Category 2	SHA
90	Sandwich toaster	Category 2	SHA
91	Saniflow	Category 2	SHA
92	Sauce maker	Category 2	SHA
93	Shoe polisher	Category 2	SHA
94	Slicer	Category 2	SHA
95	Solar lamp	Category 2	SHA
96	Steam cleaner	Category 2	SHA
97	Steam cooker	Category 2	SHA
98	Steam cooker	Category 2	SHA
99	Steam iron, Active ironing board, Ironing press	Category 2	SHA
100	Sterilising equipment	Category 2	SHA

Product code	Product name	WEEE category (2002/96/CE)	Treatment flow possibilities
101	Timer	Category 2	SHA
102	Toaster	Category 2	SHA
103	Ultrasonic cleaner	Category 2	SHA
104	Vacuum cleaner, Floor model	Category 2	SHA
105	waffle iron	Category 2	SHA
106	Watch	Category 2	SHA
107	Water filter	Category 2	SHA
108	Xhisk	Category 2	SHA
109	Yoghurt maker	Category 2	SHA
110	Centrifuge	Category 2	SHA, other
111	CRT monitor	Category 3	Screens
112	Laptop computer	Category 3	Screens, SHA
113	LCD monitor	Category 3	Screens, SHA
114	Answering machine	Category 3	SHA
115	Babyphone	Category 3	SHA
116	Calculator	Category 3	SHA
117	CD/DVD burner	Category 3	SHA
118	Central processing unit	Category 3	SHA
119	Computer keyboard	Category 3	SHA
120	copier	Category 3	SHA
121	Electric graphic board	Category 3	SHA
122	External drive	Category 3	SHA
123	External modem	Category 3	SHA
124	Fax machine	Category 3	SHA
125	GPS	Category 3	SHA
126	Handheld computer	Category 3	SHA
127	Interphone	Category 3	SHA
128	Inverter	Category 3	SHA
129	Mobile Phone	Category 3	SHA
130	Mouse	Category 3	SHA
131	Organiser	Category 3	SHA
132	PC Helmet	Category 3	SHA
133	PC loudspeaker	Category 3	SHA
134	PC microphone	Category 3	SHA
135	Printer	Category 3	SHA
136	Printer (not exclusively photo)	Category 3	SHA
137	Scanner	Category 3	SHA
138	Switch	Category 3	SHA
139	Talkie walkie	Category 3	SHA
140	Telephone (cordless/wire)	Category 3	SHA
141	USB key	Category 3	SHA
142	Webcam	Category 3	SHA
143	Wi-Fi	Category 3	SHA
144	Bank-Bill detector	Category 3	SHA, other
145	Bar code Scanner	Category 3	SHA, other
146	Cash register	Category 3	SHA, other
147	Commercial scale	Category 3	SHA, other
148	Label/tag printer	Category 3	SHA, other
149	Minitel	Category 3	SHA, other
150	Server	Category 3	SHA, other

Product code	Product name	WEEE category (2002/96/CE)	Treatment flow possibilities
151	Terminal	Category 3	SHA, other
152	CRT TV set	Category 4	Screens
153	LCD TV	Category 4	Screens, SHA
154	Plasma TV	Category 4	Screens, SHA
155	Aerial	Category 4	SHA
156	Alarm clock/Radio alarm clock	Category 4	SHA
157	Amplifier	Category 4	SHA
158	Audio & video player	Category 4	SHA
159	Battery charger	Category 4	SHA
160	Camcorder	Category 4	SHA
161	Digital camera	Category 4	SHA
162	DVD recorder	Category 4	SHA
163	Effects pedal	Category 4	SHA
164	Headphones	Category 4	SHA
165	Karaoke player	Category 4	SHA
166	Loudspeaker	Category 4	SHA
167	MD player	Category 4	SHA
168	Microphone	Category 4	SHA
169	MP3 loudspeaker	Category 4	SHA
170	Multimedia hardrive	Category 4	SHA
171	Musical instrument	Category 4	SHA
172	Personal radio	Category 4	SHA
173	Photo printer	Category 4	SHA
174	Remote control	Category 4	SHA
175	Set top box	Category 4	SHA
176	Slide projector	Category 4	SHA
177	Sound mixer/mixing board	Category 4	SHA
178	Stereo system / micro hi-fi system	Category 4	SHA
179	Tape recorder	Category 4	SHA
180	Tuner	Category 4	SHA
181	Turntable	Category 4	SHA
182	Video projector	Category 4	SHA
183	Video recorder	Category 4	SHA
184	Microfiche player	Category 4	SHA, other
185	Negatoscope	Category 4	SHA, other
186	Professionnal luminaire	Category 5	SHA, other
187	Chain saw	Category 6	SHA
188	Compressor	Category 6	SHA
189	Electrical saw	Category 6	SHA
190	Electrical screwdriver	Category 6	SHA
191	Gardening tool	Category 6	SHA
192	Glue pistol	Category 6	SHA
193	Hammer drill	Category 6	SHA
194	Mower	Category 6	SHA
195	Pressure washer	Category 6	SHA
196	Pump	Category 6	SHA
197	Sander	Category 6	SHA
198	Sewing machine	Category 6	SHA
199	Soldering iron	Category 6	SHA
200	Soldering machine	Category 6	SHA

Product code	Product name	WEEE category (2002/96/CE)	Treatment flow possibilities
201	Tool sharpener	Category 6	SHA
202	Computers for biking, diving, running, rowing	Category 7	SHA
203	Hand-held video game consoles	Category 7	SHA
204	Other small toys	Category 7	SHA
205	Other Sports equipment with electr. component	Category 7	SHA
206	Sports equipment with electric or electronic component	Category 7	SHA
207	Toys: Electric trains or car racing set	Category 7	SHA
208	Video game	Category 7	SHA
209	Coin slot machines	Category 7	SHA, other
210	Electrical scooter	Category 7	SHA, other
211	Exercise bike	Category 7	SHA, other
212	Medical treatment set	Category 8	SHA
213	Analyser	Category 8	SHA, other
214	Cardiology	Category 8	SHA, other
215	Dialysis	Category 8	SHA, other
216	Laboratory equipment for in-vitro diagnosis	Category 8	SHA, other
217	Pulmonary ventilator	Category 8	SHA, other
218	Radiotherapy equipment	Category 8	SHA, other
219	Alarm	Category 9	SHA
220	Am-/voltmeter	Category 9	SHA
221	Control panel	Category 9	SHA
222	Heating regulators	Category 9	SHA
223	Power charger	Category 9	SHA
224	Smoke detector	Category 9	SHA
225	Thermostat	Category 9	SHA
226	Weather station	Category 9	SHA
227	Automatic dispenser for hot drinks	Category 10	SHA, LHA, other
228	Automatic dispenser for hot or cold bottles, cans, drinks	Category 10	SHA, C&F, LHA, other
229	Automatic dispenser for solid products	Category 10	SHA, LHA, other
230	Automatic dispenser for money	Category 10	SHA, LHA, other
231	Parts of WEEE (printed circuit boards...)	cannot be linked up to a category	SHA, other
232	Car Fittings	Electrical equipment Out of scope of WEEE directive 2002/96/CE	SHA, other
233	Extension cord	Electrical equipment Out of scope of WEEE directive 2002/96/CE	SHA, other
234	Generator	Electrical equipment Out of scope of WEEE directive 2002/96/CE	SHA, other
235	Housing antifoudre	Electrical equipment Out of scope of WEEE directive 2002/96/CE	SHA, other
236	Light Switch	Electrical equipment Out of scope of WEEE directive 2002/96/CE	SHA, other
237	Luminaires in households	Electrical equipment Out of scope of WEEE directive 2002/96/CE	SHA, other
238	Multiplug/Plug	Electrical equipment Out of scope of WEEE directive 2002/96/CE	SHA, other
239	Batteries (free)	Non WEEE	SHA, other
240	Inkjet/laser cartridge (free)	Non WEEE	SHA, other
241	Non electric waste : coffers, kitchenware, CDs, food, etc.	Non WEEE	SHA, other
242	Packaging waste	Non WEEE	SHA, other

Annex 3: Details on components in scope


Capacitors:

All capacitors mentioned in annex II of 2002/96/CE directive are in scope:

- Electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm, or proportionately similar volume): these capacitors are polarized, marked “+” and “-“conductors and can be mainly found on printed circuit boards. Only marked “+” and/or “-“capacitors with height> 25 mm, diameter> 25 mm, or proportionately similar volume i.e. > 12,272 cm³ should be removed. We join in annex 3 a list (of all couples of min. values height-diameter which give a volume > 12,272 cm³) that could be used to decide if the electrolyte capacitor is in scope or not.



Electrolyte capacitors:

- Polychlorinated biphenyls (PCB) containing capacitors: these capacitors are not polarized (not marked “+” and/or “-“) and have theoretically no size restriction. All capacitors which may not be identified as PCB free¹⁰ shall be considered as PCB containing or PCB suspect capacitors and should be removed. The PCB suspect capacitors are usually cylindrical capacitors. Small mica and ceramic capacitors () are not PCB suspect and are out of scope.



PCB-suspect capacitors:

Batteries:

“WEEELABEX Annex A De-pollution guidelines” makes the distinction between **external batteries** which “have to be removed” as a first step of the treatment process and **internal batteries** which “have to/(could) be removed “as an identifiable (part of a) stream in the next steps of the treatment process.

Scope of batteries: all kind of batteries and accumulators (see WEEELABEX A4).

Printed circuit boards:

All printed circuit boards whose surface is greater than 10 square centimetres are in scope (see Annex II of 2002/96/CE directive; WEEELABEX A5) and should be removed for weighing. As treatment plants do not make usually the difference between printed circuit boards > 10 cm² and printed circuit boards ≤ 10 cm², we consider in this document that all printed circuit boards are in scope (whatever their size).

¹⁰ WLX A2.2: Capacitors can only be considered as PCB free, if one of the following criteria is fulfilled:

- if they have been produced after 1986 or they come from appliances produced after 1987
- if they are declared and labelled as PCB free
- if they are declared as PCB free by documents of the producing company
- if conductors are polarized and marked “+” or/and “-“ (electrolyte capacitors)

Annex 4: Couples of min. values “diameter-height” for electrolyte capacitors in scope

Diameter	Height	Volume
1,1 cm	12,9 cm	12,272 cm ³
1,2 cm	10,9 cm	12,272 cm ³
1,3 cm	9,2 cm	12,272 cm ³
1,4 cm	8,0 cm	12,272 cm ³
1,5 cm	6,9 cm	12,272 cm ³
1,6 cm	6,1 cm	12,272 cm ³
1,7 cm	5,4 cm	12,272 cm ³
1,8 cm	4,8 cm	12,272 cm ³
1,9 cm	4,3 cm	12,272 cm ³
2,0 cm	3,9 cm	12,272 cm ³
2,1 cm	3,5 cm	12,272 cm ³
2,2 cm	3,2 cm	12,272 cm ³
2,3 cm	3,0 cm	12,272 cm ³
2,4 cm	2,7 cm	12,272 cm ³
2,5 cm	2,5 cm	12,272 cm ³
2,6 cm	2,3 cm	12,272 cm ³
2,7 cm	2,1 cm	12,272 cm ³
2,8 cm	2,0 cm	12,272 cm ³
2,9 cm	1,9 cm	12,272 cm ³
3,0 cm	1,7 cm	12,272 cm ³
3,1 cm	1,6 cm	12,272 cm ³
4,1 cm	0,9 cm	12,272 cm ³
5,1 cm	0,6 cm	12,272 cm ³
6,1 cm	0,4 cm	12,272 cm ³
7,1 cm	0,3 cm	12,272 cm ³

Annex 5: Approach 3 - Standard collection data sheet for components in scope

WEEE-system :

Country :

Date :

Treatment flow :

Container n°	Net Weight (kg)	Number of appliances	If relevant, other characteristics (collection origin...)	Focus components									
				Electrolyte capacitors in scope ⁽¹⁾		PCB containing capacitors (or PCB suspect)		External batteries		Internal batteries		Printed circuit boards whose surface > 10 cm ²	
				Weight (g)	Number of units	Weight (g)	Number of units	Weight (g)	Number of units	Weight (g)	Number of units	Weight (g)	Number of units
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2													
3													
4													
5													
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...													

(1) Electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm, or proportionately similar volume)

Annex 6: Approach 4 - Standard collection data sheet for components in scope

WEEE-system :

Country :

Date :

Appliance N°	Treatment flow	Kind of product (code)	Weight (kg)	Integrity ("complete": C or "Part" : P)	If relevant, other characteristics (collection origin...)	Electrolyte capacitors in scope ⁽¹⁾		PCB containing capacitors (or PCB suspect)		External batteries		Internal batteries		Printed circuit boards whose surface > 10 cm²		Printed circuit boards whose surface ≤ 10 cm²	
						Weight (g)	Number of units	Weight (g)	Number of units	Weight (g)	Number of units	Weight (g)	Number of units	Weight (g)	Number of units	Weight (g)	Number of units
1																	
2																	
3																	
4																	
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...																	

(1) Electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm, or proportionately similar volume)

Annex 7: Quantification of mercury in FPDs backlights containing mercury

The study was conducted during the first semester of 2012 by Terra on behalf of the following working group members: Galloo, Remondis, Veolia, ERP, Eco-systèmes, and WEEE Forum.

1. Background and objectives

In a mass balance perspective, the first issue to be addressed depends on the correct quantification of the incoming mercury. Thus, the main objective of this study is to determine a representative quantity of incoming mercury in FPDs.

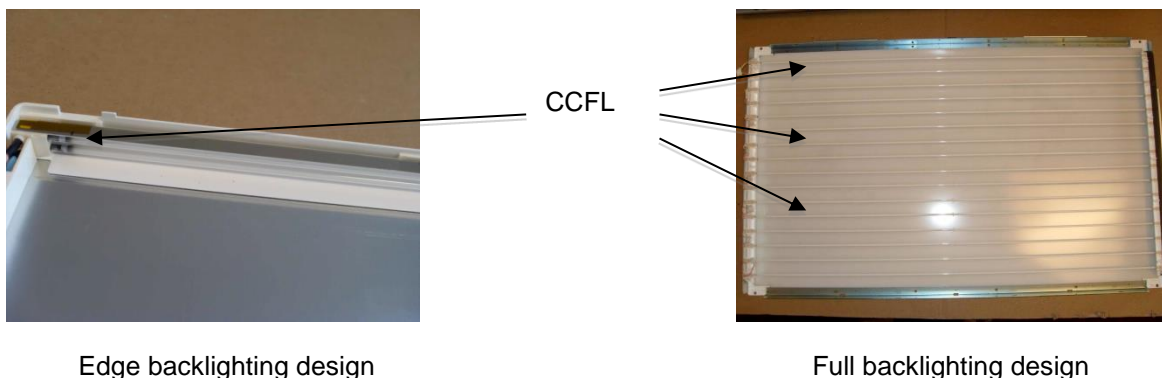
2. Main results

2.1. Specifications of the reference batch

In order to make more reliable and to simplify the quantification of incoming mercury, only some types of FPDs shall be selected for the reference batch.

Main selection criteria:

- the risk to use FPDs with broken CCFL shall be limited as much as possible:
The edge backlighting design (used for monitors and TVs under 26") offers a better protection for CCFLs during transport and handling than full backlighting design (used for TVs 26" and larger).



- the number of different FPDs sizes shall be limited: 2 or 3 at a maximum,
- the FPDs selected shall be easily available in large quantity at a treatment facility.

The 17" and 19" LCD monitors fully meet the above-mentioned criteria.

Consequently, a reference batch shall be prepared, including exclusively 17" and 19" LCD monitors containing mercury backlights (CCFLs).

2.2. Number of CCFL in monitors

During this study, 69 different FPDs (38 units 17" + 31 units 19") have been analysed: 64 units had 4 CCFLs and 5 had 2 CCFLs for backlighting.

$p\% = 5/69$ (around 7,25%)

The FPDs containing only 2 CCFLs were recent models, manufactured between 2010 and 2011.

2.3. Determination of mercury content in CCFL

This study has confirmed that the following parameters have no noticeable impact on the mercury quantity per CCFL:

- the size of the monitor: 17" or 19",
- the length of the CCFL for 19" monitors: 390 mm or 420 mm,
- the position of the CCFL: 4 different possible locations (down front, down back, up front and up back),
- the manufacturing date.

Otherwise, the brand of the monitor may have an impact but it is difficult to estimate more precisely, according to the analyses performed.

The number of CCFLs coming from monitors with 2 CCFLs (only 5 monitors in a total of 69 units) was not enough to analyse the potential impact of the number of CCFLs used for backlighting (2 or 4 lamps) on the mercury quantity per CCFL.

The resulting mercury quantity per CCFL from 17" or 19" LCD monitors can be assessed with a confidence level of 95%:

2,10 mg +/- 0,7% (i.e. from 2,087 to 2,116 mg)

3. Methodology

3.1. Method of analysis

The pyrolysis with CVAAS has been selected. The WRAP study named "The location and character of mercury in waste LCD backlights. September 2010" had already confirmed the efficiency of this method for such analyses.

Each CCFL was subject to pyrolysis in a furnace resulting in desorption of any mercury present (elemental and compound). The mercury vapour was then drawn through a detection cell and the vapour concentration was measured by the CVAAS unit.

3.2. Equipment used

Equipment based on pyrolysis with CVAAS and dedicated to fluorescent lamps manufacturing quality controls, has been selected to measure the mercury quantity in CCFL.

This device, designed by a Japanese company, NIC (Nippon Instrument Corporation) brings the following benefits:

- simple: no special sample preparation,
- quick: less than 10 min per analysis,
- reliable: high operating temperature (up to 950°C) which can guarantee the complete desorption of any forms of mercury present in the CCFL.



As this equipment is not easily available in Europe, the different analyses have been performed directly in Japan by the NIC laboratory.

3.3. Number of analyses performed

	CCFL quantity	FPD quantity
17" monitor	71	38
19" monitor	57	31
Total	128	69

As a conclusion, the mercury quantity has been measured in 128 different CCFLs coming from 69 different FPDs.

3.4. Statistical approach

The calculation of the mercury quantity in CCFLs coming from 17" or 19" LCD monitors was based on a statistical approach from 64 different values coming from 64 different FPDs. Because of the small number of monitors with 2 CCFLs for backlighting, the values coming from these monitors were not taken into account for this calculation.

It enables to stipulate that the average mercury quantity per CCFL in a batch of CCFLs coming from 17" or 19" LCD monitors has 95% of chance to be included in the confidence interval from 2,087 mg to 2,116 mg.

Annex 8: Example of sampling document

Sampling document
<p>Sampler :</p> <p>Sampling date :</p> <p>Identification</p> <p>Operator :</p> <p>Contact :</p> <p>Adresse :</p> <p>Identification of the output fraction</p> <p>WEEE category :</p> <p>Name of the fraction :</p> <p>Quantity treated :</p> <p>Output fraction quantity (exact weight or estimation) :</p> <p>Synthetic description of the process :</p> <p>Identification of the samples (mentioned on labels)</p> <p>Sample n°1</p> <p>Sample n°2</p> <p>Sample n°3</p> <p>Date of sending to the laboratory :</p> <p>Name of laboratory :</p> <p>Differences with the sampling protocol, particular events :</p>

Annex 9: Laboratory selection

Samples of output fraction from WEEE treatment have particular physical characteristics: they are very heterogeneous and they may contain metals difficult to grind for laboratories. More than the analytical skills, preparation of correct test portions for analysis, representative of the sample delivered to the laboratory, requires special expertise.

The call for tenders

To check skills of laboratory, it is necessary to get the following information:

- accreditation : laboratory have to be accredited to **ISO/IEC 17025:2005** by an accreditation body
- Schedule of accreditation (the most important document, it describes precisely the perimeter of accreditation)
- References in waste analyses
- List of material for test portion preparation (grinder...) and analyses (GC-MS, ICP-OES...)
- Guarantee that the laboratory is able to perform all operations (from the preparation of the test portion to the analyses), subcontracting is not allowed
- Detailed financial proposal

Which accreditation program is required?

Despite of the “Multilateral Agreement” which makes valid within Europe (European cooperation for Accreditation) an accreditation obtained in one country, details of the accreditation programs are different from a country to another.

In all countries, the accreditation is awarded per matrix. If it exists, accreditation for “waste”, “granular waste” or “solid waste” must be required, otherwise, laboratory must be accredited for solid and granular matrices like “soil”, “sediment” or “sludge”.

The technical schedule of accreditation describes precisely the analytical standards that the laboratory is accredited for. If standards required in the protocols described here are not included in that document, see if it contains other standards for the same substances. If so, it is necessary to validate with the laboratory their ability to implement the required standards. In this case, technical exchanges shall be necessary to validate the other standards.

Annex 10: Recap of limit values depending on output fraction analyzed

WEEE groups	Fraction	Substance to be analysed	Limit values
LHA, SHA, ICT equipment	Shredder light fraction	Cu	10 000 ppm
		Cd	100 ppm
		PCB	50 ppm (total PCB)
SHA, ICT equipment	Plastics	Bromine	700ppm
		Restricted BFRs	1 000 ppm
		HexaBB	50 ppm
FPD	Shredded mix fraction	Hg	0.5 ppm
CRT	Glass	Sulphur	5 ppm
	Glass	Lead oxide(PbO)	< 0,5 wt %
	Plastics	Bromine	700ppm
		Restricted BFRs HexaBB	1 000 ppm 50 ppm
	Ferrous metal	CRT glass	2 %
	Deflection coil	CRT glass	4 %
	Electron gun	CRT glass	8%