Waste / AFR QUALITY CONTROL MANUAL

HGRS/CTS Materials Technology

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1. ABOUT THIS MANUAL

This manual addresses both the waste / AFR quality control at an AFR platform and at a cement plant. It should help AFR managers, environmental managers and plant chemists to build up a sustainable and safe waste / AFR control. The manual will:

- describe quality-assurance and quality control (QA/QC) practices for the correct and safe utilization of waste / AFR material
- help the laboratory manager, laboratory coordinator, plant chemist and field staffs to implement QA/QC procedures including correctly following methods of waste / AFR sampling, preparation, analysis and storage
- provide links to related waste / AFR quality control information

The manufacture of cement is an energy-intensive process. The high share of energy costs in production costs of cement and steadily increasing international competition has intensified the cement industry's efforts to reduce energy costs.
The use of waste is increasingly important for the cement industry. Waste is used in cement manufacturing as an **A**lternative **F**uel and **R**aw material (AFR). Nowadays, the cement industry contributes significantly to waste management. In contrast to incinerators, the cement industry 'absorbs' all elements present in the burnt waste. In this way, it cuts both its production costs and global greenhouse gases emissions.

To follow up the process of evaluating and controlling alternative raw materials and fuels it is absolutely necessary to have secure control schemes and procedures for the waste / AFRs.

This is the fifth (05 / 2009) revised edition of the waste / AFR quality control manual, which was initially released on *HolSpace* in 2000 by R. Stenger (HGRS/CIE) and a team of AFR quality experts.

Aspects of **E**mission **M**onitoring and **R**eporting (EMR) are not covered in this manual. They are dealt within the EMR manual (can be found on the Holcim Portal), additional information is directly available at CIE/ETPS (daniele.nicosia@holcim.com) or HGRS/CMS-MT (konrad.stemmler@holcim.com).

The AFR Health and Safety aspects, too, are treated in an own manual and are dealt with only briefly in this manual. The Occupational AFR Health & Safety Manual is available on the Holcim Portal or directly at HGRS/ OH&S (albert.tien@holcim.com).

Any information and questions concerning AFR quality control can be put to the AFR Forum on the Holcim Portal or directly addressed to HGRS/CMS-MT (florian.laeng@holcim.com, willi.suter@holcim.com)

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2. AFR CONTROL SCHEME

2.1 Introduction

In this chapter the structure of a comprehensive AFR control scheme is shown. With this scheme the plants and the AFR platforms should be able to reliably determine the AFR suitable for their requirements.

2.2 Basis for an AFR Control System: AFR Specifications

The basis for AFR utilization and a corresponding control system are clearly defined specifications for AFR. Such specifications have to be established in consideration of plant specific requirements and regulatory requirements.

- *Regulatory requirements* typically relate to AFR properties that can impact health and safety of plant personal and the environment.
- *Plant specific requirements* relate to AFR properties that can impact plant operation and product (i.e. clinker, cement) quality.

Well-defined AFR specifications serve to find suitable AFR on the market, to establish specifications of candidate AFR and eventually to draw up an appropriate qualification and control scheme.

Chapter 3 explains in detail how to set up plant or platform specific AFR specifications.

2.3 Key Elements of an AFR Control Scheme

- Drawing up of specifications pertaining to a specific situation (plant or platform)
- Waste source identification and qualification for new waste types (recorded in Qualifications Master Files (see below))
- Waste delivery control on daily basis
- If pre-treatment processes are involved (e.g. at platforms): AFR product control based on clear AFR Quality Agreement between platform and co-processing cement plant(s).
- Appropriate sampling regime and documented sampling/control plans
- Laboratory facilities and equipment:
    - External verification
    - Standard operating procedures
    - Storage of samples
    - Training of laboratory staff
    - Regular inter-laboratory test (Round Robin tests)
- Data recording and statistical evaluation of customers

A typical AFR control scheme for a cement plant without pre-treatment facilities is outlined below in *Figure 1*.

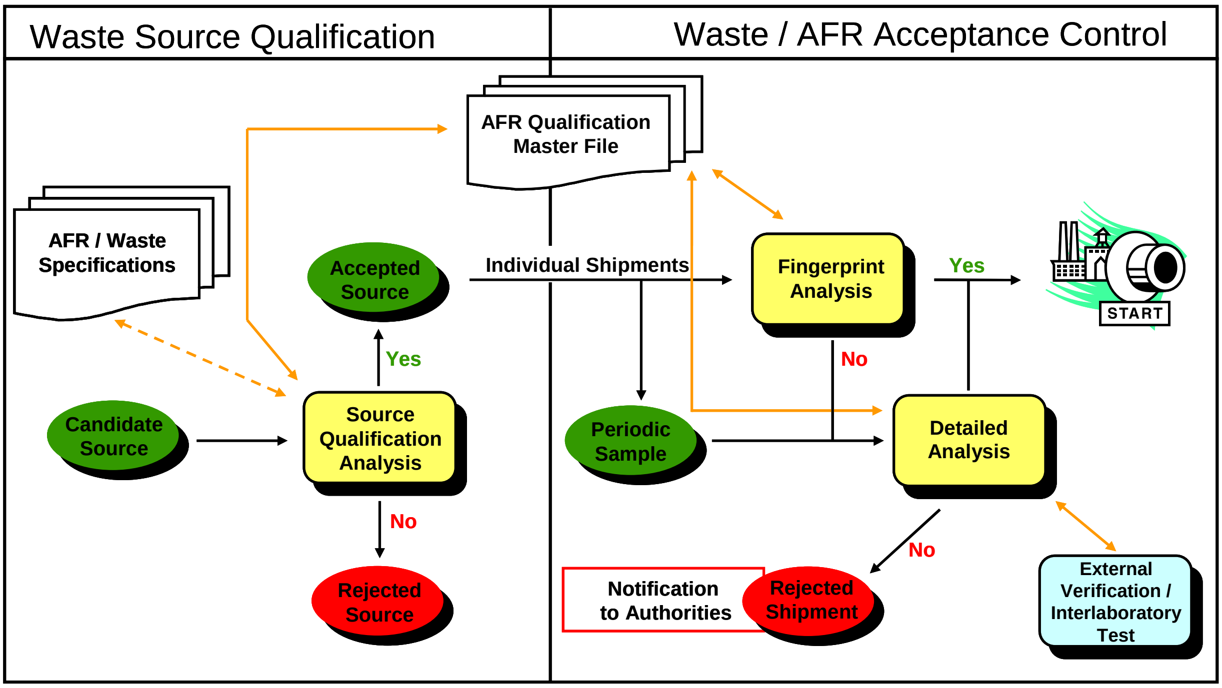


Figure 1: The AFR control scheme for a cement plant (without pre-treatment)

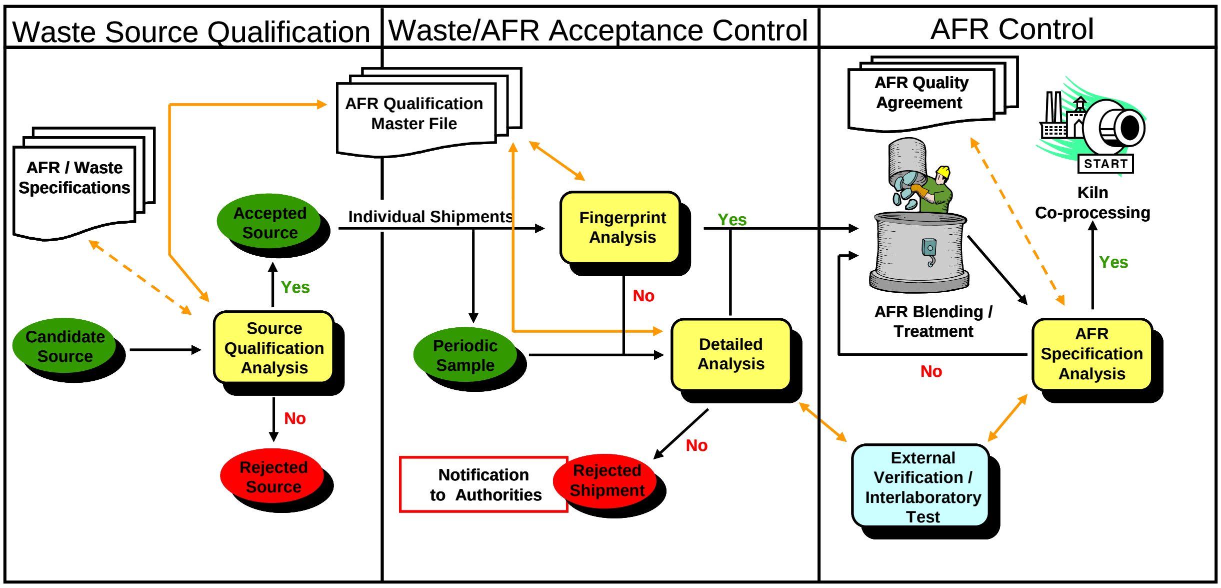


Figure 2: The AFR control scheme for a pre-treatment platform

The control scheme for an AFR platform is more complex (see *Figure 2*), since it has both interfaces to the waste producer/suppliers and to the co-processing cement plant(s). Development of the control scheme should involve the commercial department (for waste sourcing), the waste treatment and the cement plant management. Note, that the ‘AFR/Waste specifications’ used for the source qualification process do not necessarily correspond to the 'AFR Quality Agreement', which is established between AFR platform and cement plant. AFR platforms are usually more flexible than cement plants and can handle more difficult waste materials.

2.4 Waste Source Qualification

The first step in AFR utilization is to evaluate what kinds of materials are suitable for a specific plant/platform situation and to set up AFR specifications (see chapter 3). In a second step the waste market has to be evaluated, to see what kind of wastes are available and at what conditions. Once done, an all-embracing waste source qualification should be carried out. Major steps in waste source qualification are:

- Identification of customers with candidate waste materials ("candidate source")
- Evaluation of existing information (customer evaluation), i.e.:
  - Business activity or process type of waste generation
  - Intermediate disposal, storage or treatment of wastes
  - Physical and chemical characteristics of the waste
  - Health & safety data and hazards classification (MSDS if available)
  - Existing stock volumes and expected supply rates (e.g. t/week)
  - Transport conditions
- Inform the customer on permits, specifications and additional plant specific requirements.
- Full-scale testing of a representative waste sample (**source qualification analysis**) including at least all chemical and physical characteristics listed in the AFR/Waste specifications, and comparison with the specifications.
- Creation of an **AFR/Waste Qualification Master File** of the candidate waste containing all pieces of information collected (see section 2.4.2 below).
- In case of acceptance of waste source, contract and arrangement for waste deliveries.
- In case of rejection, communicate criteria for non-acceptance to the customer (through the commercial department).

The Waste Source Qualification process is of utmost importance for smooth AFR operations, since the majority of potential problems with a waste material can already be detected at this stage.

2.4.1 Key Factors to Avoid Negative Surprises

- Demand and obtain the maximum of information from the customer on process characteristics and candidate waste properties.
- Do not accept wastes based on insufficient, unsatisfying or claimed but not received information.
- Create a comprehensive and well-recorded AFR / waste qualification master file of the candidate waste.

- The AFR / waste qualification master file combined with the detailed information on the waste source process provides the basis for investigations of possible anomalies of future waste supplies.
- Establish a good supply contract by evaluating transport conditions and by defining adequate rejection/return clauses. This is particularly important for drum deliveries or other deliveries where immediate acceptance testing is not possible due to time constrains. It has to be assured that the unloaded material can always be returned in case of non-compliance.

2.4.2 AFR / Waste Qualification Master File

HGRS/CMS-MT developed an AFR / waste qualification master file (a template can be found in *Annex 2*). This file contains the following standard forms:

- *General*:
  Waste type, waste codes, waste generation source (process and business activity), producer identification, collector/customer identification, internal ID number, macroscopic properties of the waste, availability and expected deliveries, info on packaging and deliveries (containers, tanks, drums etc.), reference sample ID.
- *Properties*:
  Principal constituents, detailed physical and chemical characteristics including heavy metals.
- *Health & safety form*:
  Risk identification and characterization, R&S phrases, hazardous constituents, hazard classification, reactivity/compatibility, Material Safety Data Sheets (MSDS), H&S instructions, responsibilities.
- *Handling*:
  Transport mode (rail, truck etc.), storage, extraction from storage, transport from storage to process, dosing.

2.5 Waste Acceptance Control

Wastes can be delivered to a platform or plant for further treatment or to a plant for direct co-processing without treatment. In all cases, an appropriate acceptance control must be implemented. Acceptance control of individual shipments is carried out to

- ensure compliance with internal H&S requirements (employee’s protection);
- verify that delivered materials meet operating and permit specifications;
- take decisions for waste shipment acceptance or rejection;
- provide for a constant quality of the finished products in blending or treatment operations;
- keep records for (potential) future requests, inquiries or allegations;

Establish a shipment control sheet for reporting of analytical results. An example of a *Shipment Control File* is listed in *Annex 2*.

Delivery controls have to be carried out on each individual shipment or batch!

Exceptions can only be made after careful consideration of the type of material, the reliability of the customer and the relationship with them (see below).

The full delivery control includes two parts:

1. **Administrative verification:**
   - Control of accompanying documents (type and quantity of waste, waste code, origin of waste, carrier, date of delivery, transport code etc.)
   - Control of waste certificate (physical and chemical data, H&S data etc.)

If the necessary documentation, as agreed with the customer, is not complete, the delivery must be rejected.

2. **Analytical verification:**
   - Weighing of truck/load
   - Visual inspection
   - Sampling (representative sample)
   - Tests/analyses
     - Visual inspection
     - Rapid tests (**fingerprint**) for acceptance control
     - Detailed analysis
   - Comparison of the *Shipment Control File* against *AFR / Waste Qualification Master File* and against specifications.

As an example a procedure for incoming waste is listed in *Annex 2*. Tests for acceptance control require rapid turnaround to allow timely decisions with regard to waste shipment acceptance or rejection, so that material need not be unloaded before a decision has been made.

Ideally, unloading takes place only after analytical acceptance testing. This may however only be practical for bulk loads. In shipments comprised of numerous separate containers (e.g. drums), which are inaccessible before unloading, unloading can take place before sampling. However it should be clear within contractual agreements with the customer that in these cases unloading is only done to ensure representative samples can be taken, and, as the waste has not yet been accepted, responsibility continues to lie with the customer. Visual inspection must still proceed before and during the unloading of each container (or set of containers).

In any case, unloading is done only after having received the "Go" from the responsible person (laboratory manager, AFR manager).

Depending on the origin and the nature of the waste, it may be acceptable to carry out the full analytical program in two steps:

1. Rapid tests at delivery including for example, physical properties (visual appearance, flash point, calorific value, pH, compatibility) and other fast chemical test, depending on the nature of the waste.
2. Complete analysis in regular intervals (e.g. a composite sample/month) including all other required parameters.

The analytical results are compared to the specifications. In case of non-conformance, the customer of the waste has to be informed (through the commercial department). In case of a severe offence against the agreed material qualities, the shipment has to be rejected. The authorities may have to be notified.

It may be acceptable to **reduce** the test program upon individual deliveries if:

- ➢ The customer (waste supplier) has been qualified as a "reliable" client based on statistical evaluations over longer time periods.
- ➢ The fluctuations in the waste properties are well known based on previous test results.
- ➢ The measured values - under consideration of the fluctuations – are well below the limits given in the specifications.

Periodic quality control samples should be taken from waste shipments for external verification or for use in inter-laboratory tests. The full test program has to be carried out on these samples.

The analytical results of the individual shipments (*Shipment Control File*) together with the results of the periodic quality control samples have to be evaluated on a statistical basis (see section 2.9).

2.6 AFR Product Control (after treatment)

If wastes are processed at a platform or at a plant site to yield an AFR product, i.e. by mixing/blending of liquids and/or solids in a separate blending installation or in storage tanks, a regular product control is required to

- ➢ meet the permits and operational specifications necessary for the use in the cement plant
- ➢ assure a constant quality of the substitute fuel or substitute raw material for stable kiln operation and adequate product quality
- ➢ assure employee’s health and safety during handling and storage
- ➢ prevent environmental risks or hazards at the cement plant (emissions, effluents)

Each batch of blended/treated AFR has to be controlled prior to be delivered to a cement plant.

In case of continuous blending operations, grab samples for process control purpose should be taken on a regular basis. Sampling frequency and sample size depend on capacity of the blending installation and on the particle size of the product. The complete test program according to the AFR/Quality Agreement should be carried out on a composite sample of daily production. If the controlled batch of the finished AFR is not in compliance with the specifications, it has to be re-processed.

On request of the operator of the blending installation, **intermediate quality control tests** (with reduced test program) can be carried out to check the performance of the operation and to assess the quality of the finished product.

Table 1 shows an example of a quality control plan for waste solvents, including waste qualification testing, shipment control and finished product control. Since full testing is done on the blended batch, the delivery control testing has been reduced (e.g. metals).

2.7 External Verification

External supervision may be required by the operating permit of the cement plant/ platform in order to check the competence and the reliability of the facility's laboratory.

The verification program may include:

- Periodic cross-check analyses by an external laboratory accredited by the authorities, for example one sample every two or six months
- Laboratory audits by external verifiers, for example once per year
- A report to the authorities.

The cement plant, as a client to the blending/treatment installation, may also require external verification of the AFR laboratory with crosscheck tests.

In some cases, producers or customers of wastes have themselves requested to carry out audits on the blending plant including technical installations and laboratories.

Parameter	Waste Qualification	Delivery Control	Blended Batch Control (AFR)
Calorific value	X	X	X
Flash point	X	X	X
pH	X	X	X
Viscosity	X		X
Density	X		
Chlorine	X	X	X
Fluorine	X		X
Other halogens	X		X
Sulfur	X	X	X
Metals:			
Cd	X		X
Hg	X		X
Tl	X		X
As	X		X
Co	X		X
Ni	X		X
Se	X		X
Te	X		X
Cr	X		X
Cu	X		X
Pb	X		X
Sb	X		X
Sn	X		X
V	X		X
Be	X		X
Zn	X		X
PCB’s	X	X	X
VOC’s	X	X	X
Radioactivity	X	X	

Table 1: Quality control plan for a waste solvent blending installation

2.8 Inter-laboratory Tests (Round Robin Test)

Together with the external verification (cross-check analyses, audits), inter-laboratory round robin tests are another means of assessing and reviewing the analytical performance of the AFR laboratory.

National or international institutions usually organize inter-laboratory tests. Unfortunately, these tests are not specifically designed for waste/AFR control techniques.

Comparative tests between specialized AFR laboratories in the Holcim Group and selected external laboratories have proven to be the most effective way to verify and improve the analytical performance of the laboratories and to promote exchange of experience.

Example:

Holcim (France-Belgium) organizes regular inter-laboratory tests between specialized AFR laboratories (ca. 20 participants: Holcim (France-Belgium), HGRS, commercial waste treatment companies, external laboratories). The general conditions are:

- 2 samples (liquid and solid AFR) every 3 months are prepared and distributed.
- Analyses are carried out by AFR laboratories with their own equipment and procedures according to given specifications.
- Collection and statistical evaluation of results.
- Distribution of results together with comments/observations to all participants.
- Results are confidential (codes are used for all laboratories).

Inter-laboratory tests should be organized individually in geographical areas in accordance to the VESTA regional sub-classification, i.e. Latin America, North America, Western/Southern Europe, Central/Eastern Europe, Australia/Asia etc. HGRS/CMS-MT can give assistance in the organization and evaluation of these regional AFR inter-laboratory tests.

2.9 Statistical Evaluation of Customers

Based on the test results carried out on the individual shipments of wastes to the treatment plant or to the cement plant, a statistical evaluation of waste producers/ customers and of certain waste categories should be performed.

The evaluation has the following objectives:

- To determine the fluctuations in the properties of the individual waste types delivered.
- To update and extend the waste qualification master file.
- To review the extent of necessary analytical control of a waste type delivered by a certain customer.
- To assess the "quality" and reliability of the producer/customer from whom the waste is sourced.

- To review the contract with the producer/customer (together with the commercial department).

The prerequisites for such an evaluation are:

- A well-designed electronic database with easy and rapid access to the required data on waste categories and producers/customers of the wastes.
- Consequent and permanent feeding of the database with all analytical data generated in the laboratory including observations and comments made by the personnel.

Also refer to chapter 5.4 for data recording, processing and evaluation.

Example: Table 2 below shows analytical results (range of the analyses) for trace elements, fluoride, cyanide and ammonia in foundry sand delivered over a period of one year, incl. limit values and the number of rejections due to the different properties. Apparently, even "uncritical" material needs sometimes to be rejected.

ppm	Range	Average	Rejections	Limit Values
Pb	<1-93	12.5	-	100
As	<0.5-9.4	2.9	-	10
Cd	<0.05-0.9	0.28	-	2
Cr	<1.0-375	83.4	-	400
Ni	<1.0-2841	305	6	250
Hg	0.03-4.4	0.27	1	0.5
Zn	3.0-553	47.7	1	250
Tl	<0.1-4.4	0.44	3	0.5
CN-	<0.1-1.2	0.42	-	2
F-	<1-503	95.4	1	500
NH_3	<1-240	24	1	100

Source: Germany, Cement Review, Environmental Handbook 2003

Table 2: Analytical results for trace elements, fluoride, cyanide and ammonia in foundry sand delivered over a period of one year

Based on data from group companies (ATR, waste profiles) CMS/MT and CIE/AFR-BD have prepared fact sheets for 9 waste categories. They show average chemical and physical properties of these waste categories, similar to **Table 2** above (available on the Holcim Portal).

3. WASTE/AFR SPECIFICATIONS

Waste and AFR specifications have to take into consideration:

➢ **Plant Specific Requirements:**
Plant specific requirements will mainly refer to cement **plant operations** (i.e. stable kiln operation, handling and storage) and **clinker/cement quality**. These requirements are defined individually for each plant.

➢ **Regulatory requirements (operating permits):**
Regulatory authorities will be involved in setting up waste and/or AFR specifications. Regulatory requirements will mainly refer to **health & safety** and **environmental** aspects.

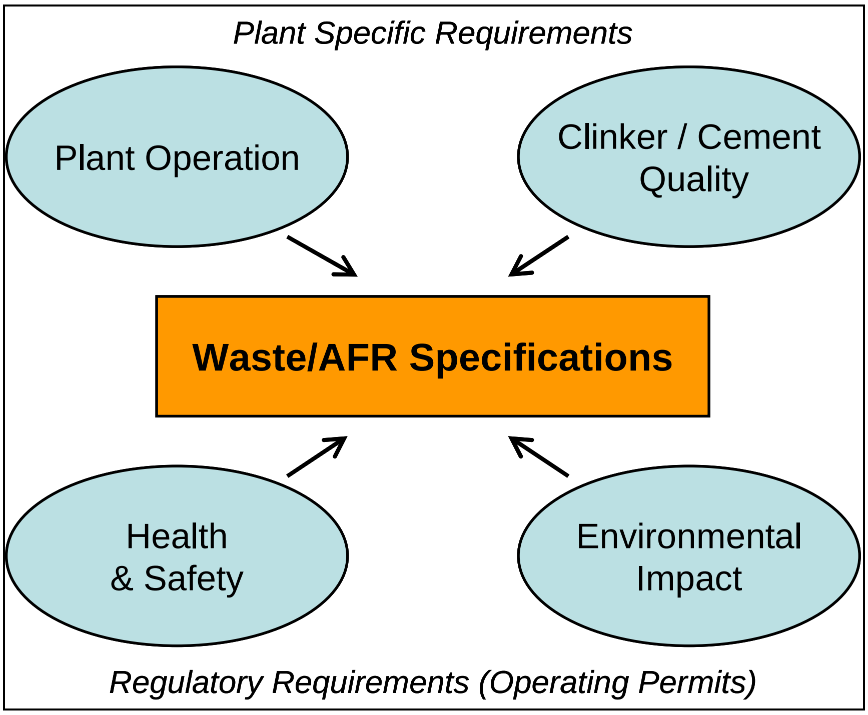


Figure 3: Key aspects influencing the waste/AFR specifications

The relationship between waste/AFR properties (i.e. specifications) and the four key aspects is shown in Figure 3 above and in detail for the various properties in Table 3. Key aspects are:

➢ **Plant operation:**
  - Burning process: moisture/water content, ash content, sulfur, alkalis, halogens, calorific value
  - Materials handling (i.e. storage and feed system): viscosity/density, solids content, pH value, immiscibility, flash point, granulometry

- **Product quality**:
  - Minor elements relevant to product performance (sulfur, halogens, heavy metals), "interfering" elements (alkalis, phosphorus, chloride, fluoride), radioactivity

- **Health and safety**:
  - Physical and chemical properties: flash point, pH value, toxic organics and inorganics, i.e. heavy metals, free cyanides, PCB’s, PAH’s, pesticides, carcinogens; radioactivity, infectious materials, free asbestos fibers

- **Environmental impact**:
  - Atmospheric emissions: volatile heavy metals (i.e. mercury), VOC's, volatile sulfur, halogens, cyanides, nitrogen, ammonia
  - Effluents and leaching properties: heavy metals, organics, other soluble components

Properties	Product Quality	Plant Operation	Health and Safety	Environment
Viscosity / density		X		
pH value		X	X	
Flash point		X	X	
Solids content		X		
Calorific value		X		
Water content		X		
Ash content / composition	X	X		
Radioactivity	X		X	X
Sulfur	X	X		X
Halogens	X	X	X	X
Heavy metals	(X)[1]		X	X
Alkalis	X	X		
Organics			X	X
Particle size		X		

Table 3: Relevance of AFR properties on product quality, plant operation, health & safety and environment

For illustration, practical examples of AFR specifications of group companies and of countries as laid down in operating permits are compiled in *Annex 3*.

[1] Heavy metal input from AFR is usually too low to cause notable effects on product quality (strength performance, setting). However, it may significantly increase the soluble chromium content of the cement.

3.1 Developing of an Individual Evaluation Scheme of Specifications

Plant specific requirements depend on the inputs from other fuels and raw materials, the substitution rate of AFR and on the technical process applied. An AFR assessment (e.g. by HGRS/CMS-TPT) is recommended to establish plant-specific specifications.

As an example the subsequent scheme applies to heavy metals in wastes to be used in clinker manufacturing and consists of the following steps:

- Establishment of average levels of heavy metals in plant clinker (including the "natural" fluctuations) as a "baseline" reference
  - without AFR
  - over a period which allows a reliable statement
- Establishment of a heavy metals balance (input – output) for each individual kiln system
  - Without AFR
- Calculation of "transfer coefficients" for all metals
  - To stack emissions
  - To clinker
  - To CKD (cement kiln dust)
- Calculation of the impact of heavy metals input through AFR substitution
- Comparison of model calculations against legal limits (e.g. stack emissions) and against "baseline" clinker levels and optimization of AFR substitution rate
- Verification of the balance model by establishment of a heavy metals balance with AFR utilization.

This evaluation scheme allows for both better prediction and optimization of the use of AFR based on the chemical composition and the individual substitution rate of the AFR under consideration.

4. SAMPLING: PROCEDURES AND EQUIPMENT

4.1 Sampling Theory

Without a sample there can be no analysis!
Without a suitable sample there should be no analysis!!

Testing of AFR materials involves a series of activities such as sampling, sample handling and preparation, the actual measuring itself and finally data processing. The reliability of such a chain of procedures depends, of course, on the weakest link as the overall random error of testing is estimated from the sum of variances of each individual step.

$$S_{tot} = \sqrt{s_1^2 + s_2^2 + s_3^2}$$

Random errors in s_1 = sampling
s_2 = sample preparation
s_3 = analytical measurement

From this law of error propagation, the following conclusions can be drawn:

- An error that can be committed in the sampling procedure cannot be compensated by increased precision in the subsequent testing steps.
- The individual errors of the sequence should be of similar size; there is no point in increasing the precision of one step as long as others are decisive for the overall error. Therefore, it is necessary to determine the precision of the individual steps in each control.

Under these aspects it is evident that sampling must be considered as a very crucial step in testing. This holds particularly true when one considers that information obtained from a few gram of material is extrapolated to quantities of several tons. And still, sampling has to be considered as the most neglected and / or misjudged aspect of control.

The frequent occurrence of all sorts of considerable errors - systematic as well as random - call for an adequate planning of sampling (procedures and techniques) on the basis of fundamental principles:

- For economical and technical reasons it is necessary to rely on a limited number of small samples to assess and control the basic material quantity.
- All sectors and particle sizes of this basic quantity must have an equal chance of being sampled (representative sampling).
- The minimum size of each individual sample is mainly dependent on the grain size distribution of the material, particularly with respect to its maximum grain size (see chapter below).
- The frequency of sampling has to be determined according to the variability of the basic quantity whereby the correlation between subsequent samples has to be considered; if the individual sample is not correlated, the sampling error

of the resulting composite sample is reduced by $\sqrt{N}$, where N is the number of subsamples.

- Each subsequent step of reduction in sample size by crushing, grinding and splitting represents a further step of sampling with its own inherent error.
- For further sample treatment any alteration of the sample, e.g. by the loss of fines as dust or by contamination has to be avoided (systematic errors).

4.1.1 Types of Sampling Error

In the sampling theory of Gy are a number of different types of error identified that can occur in sampling as a result of heterogeneity in the waste and failure to correctly define the appropriate shape and volume of material for inclusion in the sample. Understanding the types and sources of the errors is an important step toward *avoiding* them. In qualitative terms, these errors include the following:

- *Fundamental error*, which is caused by differences in the composition of individual particles in the waste.
- Errors due to *segregation* and *grouping* of particles and the constituent associated with the particles.
- Errors due to various types of trends including small-scale trends, large-scale trends, or cycles.
- Errors due to defining (or *delimiting*) the sample space and *extracting* the sample from the defined area.
- Errors due to *preparation* of the sample, including shipping and handling. (Note that the term "preparation," as used here, describes all the activities that take place after the primary sample is obtained in the field)

In the following table strategies are described to reduce the different errors that can occur:

Type of Sampling Error	**Strategy To Minimize or Reduce Error**
Fundamental Error	❑ To reduce variability caused by fundamental error, increase the volume of the sample. ❑ To reduce the volume of the sample and maintain low fundamental error, perform particle-size reduction followed by sub sampling. ❑ When volatile constituents are of interest, do not grind or mix the sample. Rather, take samples using a method that minimizes disturbances of the sample material
Grouping and Segregation Error	❑ To minimize grouping error, take many increments. ❑ To minimize segregation error, homogenize the sample (but beware of techniques that promote segregation)

Type of Sampling Error	**Strategy To Minimize or Reduce Error**
Increment Delimitation /Extraction Errors	❑ Select sampling devices that delimit and extract the sample so that all material that should be included in the sample is captured and retained by the device
Preparation Error	❑ Take steps to prevent contamination of the sample during field handling and shipment. ❑ Prevent loss of volatile constituents through proper storage and handling. ❑ Minimize chemical transformations via proper storage and chemical/physical preservation. ❑ Take care to avoid unintentional mistakes when labeling sample containers, completing other documentation, and handling and weighing samples.

4.1.2 Determining the Optimal Mass of a Sample to Reduce the Fundamental Error

It is recommended determining the appropriate size (i.e. mass or volume), shape, and orientation of the primary field sample. For heterogeneous materials, the size, shape, and orientation of each field sample will affect the analytical result. To determine the optimal mass (or weight) of samples to be collected in the field, you should consider several key factors:

- ➢ The number and type of chemical and/or physical analyses to be performed on each sample, including extra volumes required for QA/QC.
- ➢ Practical constraints, such as the available volume of the material and the ability to collect, transport, and store the samples.
- ➢ The characteristics of the matrix (such as particulate solid, sludge, liquid, etc.).
- ➢ Health and safety concerns (e.g., acutely toxic, corrosive).
- ➢ Availability of equipment and personnel to perform particle-size reduction (if needed) in the field rather than within a laboratory.

Often, the weight (or mass) of a field sample is determined by “whatever will fit into the jar.” While this criterion may be adequate for some wastes or media, it can introduce serious biases – *especially in the case of sampling particulate solids*.

If a sample of particulate material is to be representative, then it needs to be representative of the largest particles of interest. This is relevant if the constituent of concern is not uniformly distributed across all the particle size fractions.

If the constituent(s) of concern is uniformly distributed throughout all the particle size fractions, then determination of the optimal sample mass using Gy’s approach will not improve the representativeness of the sample. Homogeneous or uniform distribution of contaminants among all particle sizes, however, is not a realistic assumption, especially for contaminated soils. In contaminated soils, concentrations of metals tend to be higher in the clay- and silt-size fractions and organic contaminants tend to be associated with organic matter and fines in the soil.

The following equations provide a “rule of thumb” approach for determining the particle-size sample-weight relationship sufficient to maintain fundamental error (as measured by the standard deviation of the fundamental error) within desired limits. A detailed quantitative method is given by Gy (1998).

The variance of the fundamental error (s^2_{FE}) is directly proportional to the size of the largest particle and inversely proportional to the mass of the sample. To calculate the appropriate mass of the sample, the following equation is based on a standard deviation of the fundamental error of 5 percent (s_{FE} = ±5%):

$M_S \geq 10000\ d^3$	**Equation 1**

where M_S is the mass of the sample in grams (g) and d of the diameter of the largest particle in centimetres (cm).

Alternatively, it is possible to accept an error of s_{FE} = ±16%, what leads to the equation:

$M_S \geq 1000\ d^3$	**Equation 2**

With these rules of thumb the right sample size could be defined and so all particle sizes should be represented in the sample.

4.2 Sampling Procedures

In the following, the sampling procedures for sampling wastes with regard to receive an adequate sample are described. The obtained sample should allow determining the characteristic chemical and physical properties of the waste and the impact on the environment.

In general representative samples should be taken from each shipment of waste to the cement plant. For creating a comprehensive sampling procedure, the following criteria have to be considered:

- Determination of the basic material quantity (truck, barrel, silo volume, stock pile)
- Estimation of the minimum size for each individual sample
- Variability of material to be sampled (estimation of standard derivation by experiment) and from this the sampling interval)
- Sampling equipment
- OH &S equipment (PPE)

The major problems encountered in taking representative samples are:

- Inaccessibility of tanks, trucks, ships, containers, stockpiles etc.
- Segregation during transport and storage
- Immiscibility of liquids
- Contamination of liquids with solid parts
- Excessive grain size of solid bulk materials

- Toxicity of the waste
- Not fulfilling the health & safety restrictions for the sampling person

In several countries, there are standards for the sampling procedure. If ever possible, they should be followed. However, in most cases the standard methods are not applicable in waste control. Nevertheless for each individual plant or AFR treatment facility separate procedures have to be developed depending also on local regulations and the used AFRs.

For the sampler written instructions must be available. The instructions must take into consideration:

- The physical nature (liquid, solid, pasty) and the volume of the material.
- The containment of the waste deliveries (trucks, containers, drums, cans etc.).
- The toxicity and H&S risks of the material.

The sampler must receive extensive training in health & safety aspect and preventive/protective measures, in addition to the training in the regular sampling procedures (see also chapter 6).

Adequate sampling equipment must be available at each sampling station. In addition, dedicated and labeled containers must be provided at each sampling station for disposal of waste arising with the preparation. Surplus samples must be returned to the original containments for further processing.

4.3 Sampling of Liquids

4.3.1 Sampling of Bulk Liquids

For the sampling of bulk liquids (from tank trucks, i.e. solvents, waste oil etc.) the following equipment is recommended (for a list of suppliers see end of this chapter):

- Standard aluminum or copper sampling tubes (2.5 and 1.2 m length, approx. 20 - 30 mm diameter) with ball valves at one end (could be a self-made device)
- Alternative equipment: piston sampler
- Aluminum cans of different volumes (1, 5, 10 l) with "wide-mouth" openings
- Plastic bottles (PE or PTFE) of different volumes (250, 500, 1000 ml)
- Rags for cleaning the sampling tools.

Example 1: General procedure for bulk liquid sampling from a truck with a standard copper sampling tube:

Pressure has to be released slowly and cautiously from closed vessels or drums prior to complete opening. Samples are taken with the 2.5 m sampling tube from each compartment of the truck or container (ca. 1 - 2 l each). The sampling tube has to be rinsed with the liquid prior to sampling. The tube is inserted vertically down to the bottom of the tank with the valve end down. After closing of the valve, the tube is lifted and the liquid is filled into the temporary sample container (see Figure 4). Sub-samples are combined and, after homogenization (agitation), a volume of approx. 1 l is transferred to a plastic bottle and sent to the laboratory for analysis. The tube must be cleaned after each set of samples to avoid contamination of the next sample. The plastic bottle must be carefully labeled with sample ID, date etc..

Figure 4: For liquids: A standard aluminum or copper sampling tube (2.5 and 1.2 m length, approx. 20 - 30 mm diameter) with ball valves at one end is used.

Example 2: General procedure for bulk liquid sampling from a truck with a Piston sampler:

An alternative method to sample liquids from trucks or drums is the use of a piston sampler. The piston sampler has to be positioned over the surface of the waste. The string has to be fixed (e.g. with your foot) (Figure 5, left side) and the tube is inserted vertically down to the bottom of the tank (Figure 5, right side). The tube is lifted and the liquid is filled into cans. All other tasks are similar to the first example.

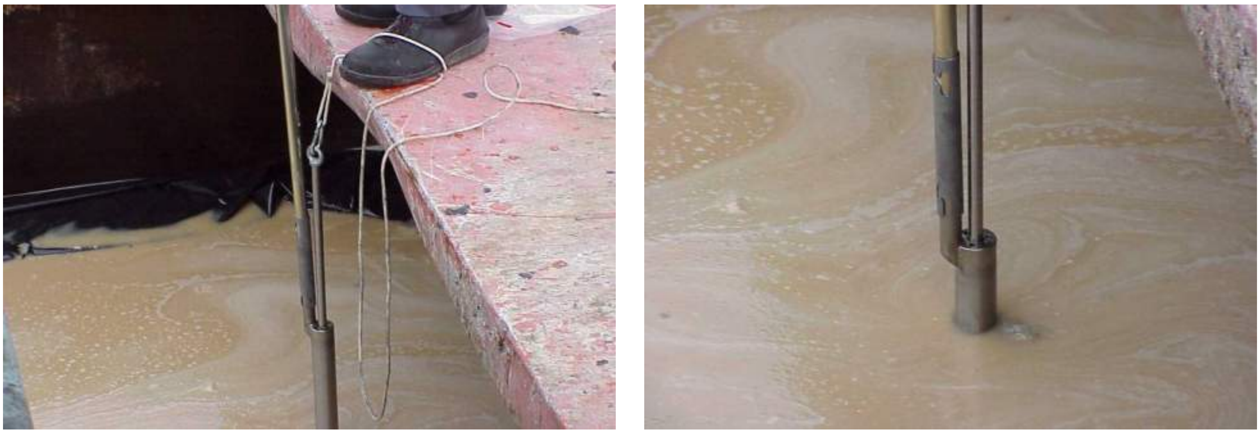


Figure 5: Use of the piston sampler for liquid waste

4.3.2 <u>Sampling of Drums or Cans (smaller amounts)</u>

➢ Drums (200 l):

In general the above-mentioned sample equipment for bulk liquids in a smaller size can be used for drum sampling. The samples are taken from each drum (approx. 0.125 l each). One sub-sample of approx. 1 l per every eight drums is combined and homogenized. One finished sample of approx. 1 l is blended and homogenized from several individual batches of eight drums each and transferred to the laboratory. The remaining sample quantity is returned to a selected disposal drum. The finished sample must be carefully labeled.

An alternative sampling device is the *transparent liquid sampler*. The sampling device has to be positioned over the surface of the waste. The metal rod with the sealing is lowered down to the bottom of the tank followed by the vertical insertion of the plastic tube. The plastic tube is sealed to the metal rod and is lifted (see **Figure 6**). Now it is easily visible if more than one phase occurs (e.g. oily / aqueous). All other procedures in this context are similar to the above-described devices.

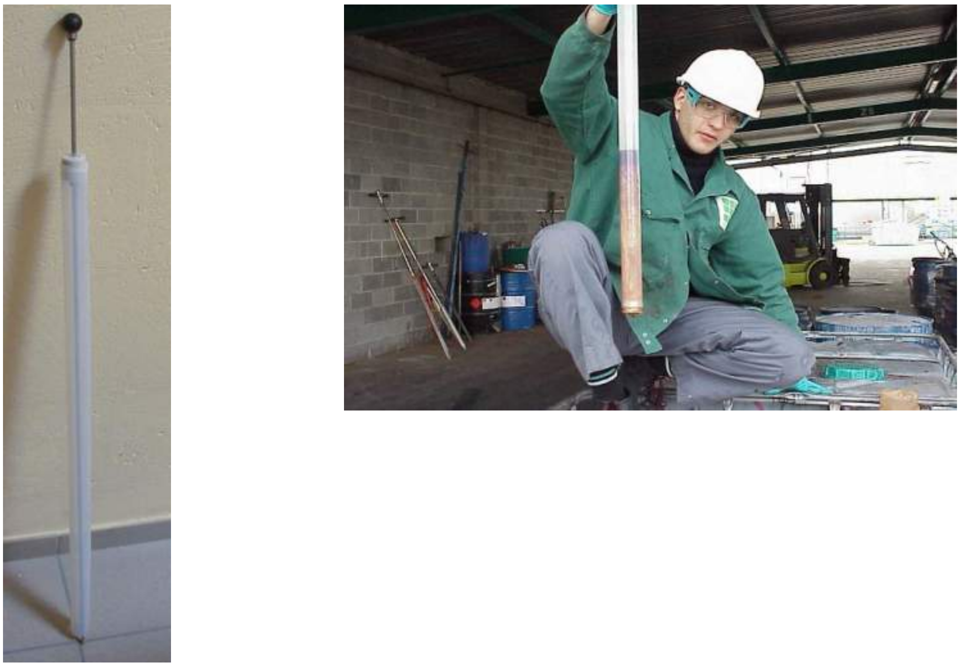


Figure 6: Use of the transparent liquid sampler for smaller amounts of liquid waste.

➢ Cans (small volume):

Smaller sampler of the above-described samplers should be used to sample the cans. Approx. 10 % of all cans must be sampled at minimum (random samples). The sampling procedures correspond to the procedures applied in the sampling of drums.

Blended and homogenized samples of approx. 1 l for each phase occurring in the can (liquid, solid, pasty) are transferred to the laboratory. Several spot samples should be retained for reference.

Due to the inherent problems in sampling (heterogeneous) wastes from a large number of small-volume containments, it is recommended to add a secondary (automatic) sampling station prior to the pre-mixer of the blending installation.

4.3.3 Sampling of Liquid Finished Products

Samples are taken continuously or discontinuously from blending/storage tanks during loading of the trucks. The liquid should be permanently agitated in the tanks. A total volume of approx. 10 l is collected over the whole sampling period. After homogenization and splitting, a sub-sample of approx. 0.5 l is transferred to the laboratory.

Sampling of intermediate control samples is done off-line periodically from the tank outlet via a standard ball or gate valve tap. Liquids in tanks without continuous agitation must be agitated (with pumps) prior to sampling for a period of approx. 4 hours at minimum. Prior to collection of the sample, a sufficient volume of the liquid is allowed to flush into a waste containment.

4.4 Sampling of Pasty and Solid Materials

4.4.1 Sampling of Bulk Pasty / Solid Materials

For the sampling of bulk pasty/solid materials the following equipment is recommended (for a list of suppliers see end of this chapter):

- An aluminum shovel (capacity approx. 0.5 - 1 l) with both long and short handles
- A peat sampler
- A core sampler
- Aluminum cans of different volumes (1, 5, 10 l) with "wide-mouth" openings
- Plastic bottles (PE or PTFE) of different volumes (250, 500, 1000 ml)
- Plastic bags (various sizes)
- Rags for cleaning the sampling tools

Example 1: General procedure for sampling of bulk solids from piles, open containers or trucks with a peat sampler:

Depending on the amount of material and the largest grain size (see *chapter 4.1*) several sub-samples are taken from different parts and levels of the material with a peat sampler. The sampling device has to be inserted into the waste, has to be rotated by 180° and pulled off. The peat sampler is then removed and the sub-sample is combined with the other sub-samples. The sub-samples are combined, manually homogenized and split by quartering. The finished sample (plastic bottle or bag) is adequately labeled and transferred to the laboratory. The peat sampler must be cleaned with a rag after each set of samples. The rags are disposed of in a separate waste bin (see **Figure 7**).

Figure 7: Use of a peat sampler for sampling of piles.

Example 2: General procedure for sampling of bulk pasty wastes from open containers or trucks with a peat sampler:

Depending on the amount of material and the largest size (see chapter 4.1), several sub-samples are taken from different parts and if possible from different levels of the material with a peat sampler. The sampling device has to be inserted into the waste, has to be rotated by 180° and pulled off. The peat sampler is then removed and the sub-sample is combined with the other sub-samples. The sub-samples are combined, manually homogenized and split (if possible) by quartering. The finished sample (plastic bottle or bag) is adequately labeled and transferred to the laboratory. The peat sampler must be cleaned with a rag after each set of samples. The rags are disposed of in a separate waste bin (see Figure 8 below).

Figure 8: Use of the Peat sampler for pasty waste

As an alternative sampler for pasty and solid materials an aluminum shovel (with stable handle) can be used. The beforehand described procedure has to be applied.

4.4.2 Sampling of Small Amounts of Pasty / Solid Materials

For the sampling of small amounts of pasty / solid materials the following equipment is recommended (for a list of suppliers see end of this chapter):

- An aluminum shovel (capacity approx. 0.5 - 1 l) with both long and short handles
- A peat sampler
- A core sampler
- Aluminum cans of different volumes (1, 5, 10 l) with "wide-mouth" openings
- Plastic bottles (PE or PTFE) of different volumes (250, 500, 1000 ml)
- Plastic bags (various sizes)
- Rags for cleaning the sampling tools.

Example 1: General procedure for sampling of small amounts of pasties from drums with a core sampler:

The Core Sampler has to be inserted vertically into the waste, has to be rotated for 180° and pulled off (see **Figure 9**). One sub-sample per drum is combined with the other sub-samples and homogenized. One finished sample of approx. 1 l is blended and homogenized from several individual sub-samples of each drum and is transferred to the laboratory. The remaining sample quantity is returned to a selected disposal drum. The finished sample must be carefully labeled.

Figure 9:Use of the core sampler for pasty waste

4.4.3 Sampling of Pasty / Solid Finished Products (impregnated saw dust, shredded plastics, etc)

In a continuous mixing/shredding process, grab samples of approx. 1 l are taken manually with a sampling shovel from the conveyor system or from the process outlet (mixing drum, shredder), for example once per hour. Hourly samples are blended, homogenized and split (by quartering or riffle splitter). Depending on the homogeneity of the product, samples are transferred frequently to the laboratory.

Automatic or semi-automatic sampling from continuous blending is recommended, for example directly from the conveyor system with a hammer sampler, flap sampler or chute sampler (depending on stickiness etc. of the material). An example of such a sampler is given in Figure 10. The blended sample should represent a total batch of approx. 150 t at maximum.

Figure 10: Sampling installation for impregnated saw dust (finished product below drum sieve)

4.5 Necessary Quantities of Samples for the Laboratory

The table below indicates the approximate volume of sample which is required for analysis, storage and external verification. This does not correspond to the amount of material required for a representative sample.

	in L	Analysis	Storage	Others*	Total
Bulk and drums	Liquids	**0.1 -0.5**	**0.3**	**0.25**	**1**
	Solids	**3 - 5**	**0.3**		**5**
	Pasty	**0.5**	**0.3**		**1**
Storage tank		**0.5**	**0.25**	**0.5**	**1**
				* e.g. external	

Table 4: Quantities of samples required for analyses, storage and external verification

4.6 Sample Storage

Samples must be retained in carefully labeled and sealed bottles in a separate storage room close to the laboratory. The storage room must be equipped with adequate air ventilation, temperature/humidity control and exhaust air filter system (active carbon) to the outside.

Typical duration of sample storage (if not otherwise specified in the operating permit):

- Approx. 3 years for reference samples from the waste qualification tests[2].
- Approx. 3 months for daily delivery samples.
- Approx. 3 months for finished product or dispatch samples.

4.7 Health & Safety Provisions During Sampling

During sampling, the sampler must follow adequate Health & Safety measures (depending also on the Risk and Safety phrases [www.ilo.org.]) such as:

- Informing other persons about place and time of sampling activities.
- Strictly following the existing work instructions.
- Wearing fully protective clothing, resistant against aggressive chemicals; including: one-way gloves, safety glasses, safety shoes).
- Wearing a respirator or even a full-scale oxygen mask.

[2]) (Bio-) Degradable samples cannot be stored over such a long period.

- Avoiding direct skin contact with (hazardous) wastes.
- Avoiding any spill of chemicals and/or taking adequate counter measures immediately in case of a spill.
- Carefully disposing of contaminated materials such as rags, gloves etc.

The Occupational AFR Health & Safety Manual gives detailed support in any topic of Health & Safety

A comprehensive Occupational AFR Health & Safety Manual is available on the Holcim Portal or directly at HGRS/OH&S (albert.tien@holcim.com).

4.8 List of Suppliers and Literature

List of possible suppliers of sampling equipment:

Supplier	Website Address
Aquatic Research Instruments Eijkelkamp Enviroequip	www.aquaticresearch.com www.eijkelkamp.com www.enviroequip.com

Literature:

Gy, P Sampling for Analytical Purpose. Wiley: New York 1998	Book
Pitard FF. Pierre Gy's Sampling Theory and Sampling Practice (2nd edn). CRC Press: Boca Raton, FL, USA, 1993	Book
RCRA Waste Sampling Draft Technical Guide, Planning, Implementation and Assessment, 2002, EPA-D-02-002	Document available on www.epa.gov/osw
ASTM Vol. 11.04, September 2003 Environmental Assessment; Hazardous Substances and Oil Spill Responses; Waste Management; Environmental Risk Management	www.astm.org
Scoribel: Database: Quality System Documents, Scoribel S.A:	Documentation on Holcim Portal

5. LABORATORY

5.1 General

In an AFR pre-treatment facility a fully equipped laboratory needs to be established with the purpose of sophisticated control of also unknown wastes. For an AFR laboratory in a cement plant, different scenarios are possible. The design and the instrumentation depend on:

- Legislations and limits according to regional laws and permits
- The number and type of used AFR materials
- The general quality control concept of the Group Company
- The reliability of the customers
- Capital investments; personnel requirements; availability of space
- Availability of an external laboratory (independent, third party or on group company level), which can carry out special and time consuming analyses

For cement plants that start using AFR materials they can extend the standard process quality laboratory to include AFR analysis in a three-step approach (see Figure 11).

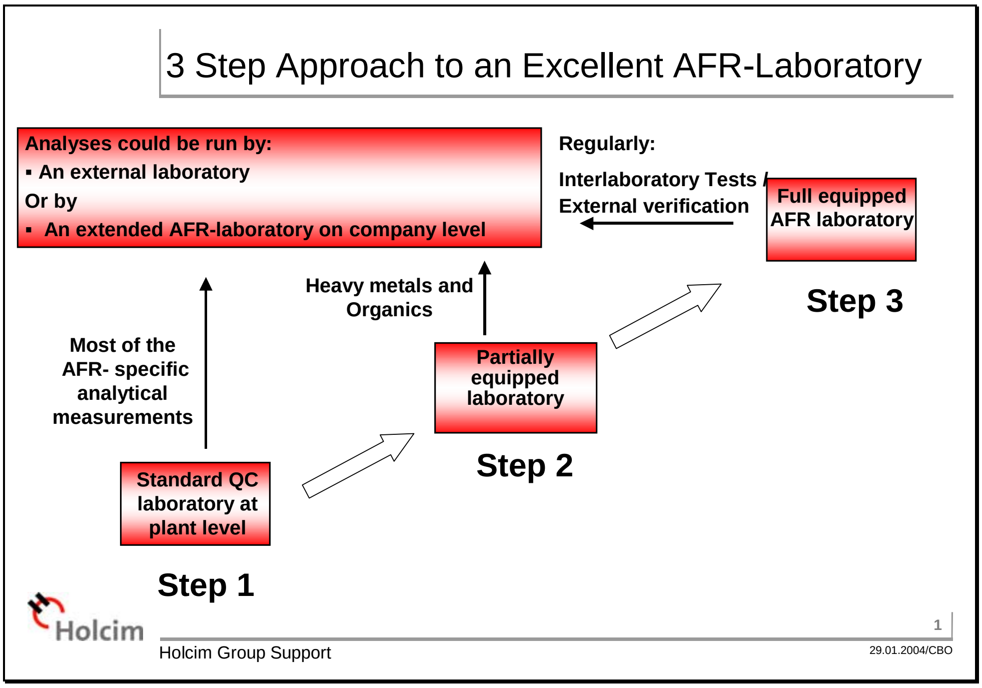


Figure 11: 3-step approach to a full-equipped AFR laboratory

In **Step 1** it should be determined what kind of analytical equipment and sample preparation equipment for the purpose of analyzing AFR materials is available at the QC laboratory in a cement plant.

Normally the following equipment is available at a cement plant QC laboratory:

- Bomb calorimeter (for heat value CV)
- Titration equipment (for Cl-content)
- Furnace (moisture)
- pH-Meter
- Sieves (particle size)
- XRF-spectrometer (semi-quantitative HM scan, ash analysis)
- Infrared based S/C analyzer (e.g. LECO, for S-content)

In this first step, the volumes of AFR are only low and/or the uniformity of the material is good. Basic parameters such as calorific value or moisture can be determined by the plant laboratory, other analyses should be carried out at an external laboratory. For Step 1 no additional costs should emerge. The laboratory is at this stage not capable to handle hazardous wastes.

In Step 2 additional equipment (low investments) should be considered, dependent on the foreseen and used AFR materials:

- Equipment for sample preparation:
  - Laboratory mill
  - Shredder
- Flashpoint analyzer
- Viscosimeter (for viscosity)
- Densimeter (for density)
- Scintillometer (for radioactivity)
- Karl-Fischer-Apparatus (for water content)

Depending on the AFR materials and the specifications, it is possible to carry out all process related analyses with the equipment listed here and in step 1. The space requirement for these instruments is low. Most of the instruments are easy to operate for laboratory technicians. An external laboratory should carry out organics, trace elements and other sophisticated analyses, if it is necessary.

In **Step 3** the objective is to establish a fully equipped AFR-laboratory. The investments for the required instruments are higher and the laboratory personnel need extended training for maintaining and running the instruments. The analyses can also be time consuming. Depending on the material and the necessary analysis these instruments are:

- Ion-selective Electrode (for Fluoride)
- Mercury (Hg) Analyzer
- ICP-OES / AAS (for trace elements)
  - Alternative: EDXRF bench-top analyzer (lower price, easier handling, but higher detection limits)
- Gas chromatograph (GC) with different detectors (MSD, FID, ECD) (for organic compounds such as pesticides or PCBs).For the upgrade in step 3 costs of approx. 250’000 € can be expected. Also additional space is required for the instruments. For internal and external verification, intense inter-laboratory tests

with different laboratories should be done to establish and verify these sophisticated methods.

More details about the mentioned analytical equipment can be found in the following chapters.

5.2 Laboratory Equipment

A list of laboratory equipment for analyzing AFR materials is given in Table 5. The list includes analytical instruments, which are usually required in the control of hazardous/non-hazardous materials. It does not claim to be complete and for certain parameters several methods/instruments can be used. Alternative methods are indicated where appropriate. It should also be pointed out, that the list is focused on the needs of a cement plant (standard - extended). Pre-treatment platforms will require nearly all of the listed equipment.

A table of test equipment together with recommended international suppliers incl. links to their web pages and average prices is presented in *Annex 4*. This list contains the well-known suppliers but there are also smaller or regional companies that may not be included in this list. Selection of equipment should be based on

- suitability and price of equipment
- services provided by the supplier (response time, maintenance, spare parts, training, language capabilities, etc)
- standardization within group company
- local or country specific preferences

Service contracts for critical analytical equipment, such as gas chromatographs or ICP spectrometers, are recommended to assure rapid maintenance response in case of equipment failure (as recommended for the XRF spectrometer in the cement laboratory.)

Prices shown in *Annex 4* and the following sections are approximate, mainly based on European experience and may vary in other geographical areas. Addresses of local representations of many international suppliers can be found on the Internet.

Annex 4 also contains a list for standard reference samples used for the calibration of the test equipment or used for the verification of test results, together with suppliers of the standards and of standard chemicals.

No.	Parameter	Equipment	Standard	Extended
Chemical Analyses				
1	**Chloride**	Titrator/Electrode	**X**	
2	**Water**	KF- Titrator	**X**	
3	**Fluoride**	Ion-Selective Electrode		X
4	**Sulfur**	Sulfur Analyzer		X
5	**Ash Composition**	XRF	**X**[3]	
6	**Carbon (TOC)**[4]**)**	Carbon Analyzer		X
7	**Anions, NH_4^+**	UV/VIS		X
8	**Trace elements**	ICP-OES, EDXRF, AAS	**X**	
9	**Mercury (Hg)**	AMA-245		X
10	**Nitrogen**	Kjeldahl Destillator		X
11	**Organics**	GC-MSD		X[5]
12	**Organics**	GC-FID		**X**[6]
13	**PCB**	GC-ECD		**X**
14	**Compatibility**	Glassware	**X**	
Physical Analyses				
15	**Calorific Value (CV)**	Bomb Calorimeter	**X**	
16	**Flash Point**	Flash Point Analyzer	**X**	
17	**pH-Value**	pH Meter	**X**	
18	**Density**	Densimeter		X
19	**Viscosity**	Viscosimeter		X
20	**Radioactivity**	Scintillometer		X[7])
21	**Ash, Volatiles**	Muffle Furnace	**X**	
22	**Moisture**	Drying Oven	**X**	
23	**Granulometry**	Sieves	**X**	
Sample preparation				
24	**Sample Digestion**	Microwave Furnace	**X**	
25	**Size Reduction**	Laboratory Mill, Shredder	**X**	
26	**Auxiliaries**	Balances	**X**	
27	**Auxiliaries**	Evaporator	**X**	
28	**Auxiliaries**	Centrifuge	**X**	
29	**Auxiliaries**	Ultrasonic Bath	**X**	
30	**Auxiliaries**	Suprapure Water System	**X**	
31	**Auxilaries**	Fume Hood	**X**	

Table 5*:* Standard and Extended AFR Laboratory Equipment

[3]) Cement plant's XRF spectrometer can be utilized
[4]) TOC = Total Organic Carbon; for alternative raw materials only
[5]) For identification/quantification of (unknown) toxic organic components (safety aspects)
[6]) For comparative fingerprint analysis only; not required if GC-MSD is available
[7]) Simple gamma counter may be sufficient in most cases

5.2.1 Comments on the Analytical Equipment

In the following, a short overview of commercially available instruments for analytic laboratories is given and commented. The list does not claim to be complete; prices are based on year 2003.

- **Titrator/Electrode; Determination of Chloride (1)**

  Used for determination of chloride by potentiometric titration. For combustibles the washings of the combustion bomb are usually analyzed, non-combustible samples require digestion.
  Suppliers: Mettler-Toledo, Metrohm, Thermo Scientific, WTW *(Prize (€):10'000)*
  Alternative Methods: XRF (less sample preparation); Ion Chromatography; LabTech offers analyzer for direct chloride analysis (integrated combustion process)

- **Titrator/Electrode; Determination of Water content (2)**

  Titrator equipment based on the volumetric or the coulometric principle is available; coulometric titrators are very accurate and used for low water contents (< 0.2%) but are not recommended for AFR. Special furnaces which drive out the moisture into the reaction vessel allow direct analysis of solid samples. A series of Karl-Fischer reagents is available and can be selected according to sample properties (beneficial for electrode life-time).
  Suppliers: Mettler-Toledo, Metrohm, Schott Instruments, Thermo Scientific, WTW *(Prize (€):10'000)*
  Alternative Methods: Azeotropic distillation

- **Ion-selective electrodes; Determination of Fluoride (3), Cyanide, Ammonia**

  Ion-selective electrodes are mainly applied for fluoride analysis. Alternatively it can be used in the analysis of other halogens, cyanides or ammonia in liquid samples. A complete system consists of the ion-selective electrode, a reference electrode and an ion meter (or high impedance voltmeter).
  Suppliers: Mettler-Toledo, Metrohm, WTW, Thermo Scientific *(Prize (€):5'000)*
  Alternative Methods: UV/VIS spectrometry (see below); Ion chromatography

- **Sulfur analyzer (4)**

  Sulfur can be determined by a variety of methods. In combustible materials it can be determined by means of gravimetric analysis (precipitation with Ba reagents), titration, spectrophotometry or ion chromatography using the solution from the combustion bomb.
  The analysis of sulfur in non-combustible solid materials might require a dedicated sulfur analyzer based on high temperature combustion and subsequent infrared detection. An alternative way to determine sulfur is by using XRF or ED-XRF equipment.
  Suppliers: Leco, Horiba Jobin-Yvon, Shimadzu, Antek, LabTech, Analytik Jena, Ströhlein *(Prize (€):25 - 40'000)*

- **XRF-spectrometry; Determination of the ash composition (5)**

  Cement plant's XRF spectrometer should be utilized where possible, alternatively an: EDXRF system might be purchased.
  Determination of major elements like SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, K_2O, Na_2O, TiO_2, P_2O_5, Mn_2O_3, Cl, etc.
  Suppliers: Spectro, Bruker, Panalytical, Thermo Scientific (ARL) *(Prize (€): 60-150'000)*
  Alternative Method: ICP-OES

- **Carbon Analyzer; e.g. determination of total organic carbon (TOC) (6)**

  Organic components (TOC = Total Organic Carbon) in solid raw materials are determined by means of a carbon analyzer based on the same measuring principle as a sulfur analyzer (see (4) above).
  Sample pre-treatment with acids (HCl or H_3PO_4) to remove interfering carbonate components prior to analysis may be required.
  Suppliers: Leco, Rosemount Analytical, Shimadzu, Ströhlein *(Prize (€): 25 - 40'000)*

- **UV/VIS spectrometer; Determination of Anions and Ammonium (7)**

  Various anions (e.g. F^-, CN^-, SO_4^{2-}, PO_4^{3-} but also NH_4^+) can be detected by colorimetry, i.e. colouring reaction of the anion with a specific agent in aqueous solution. Quantification is realized by traditional ultraviolet / visible (UV/VIS) absorption spectrometry. Anion specific testing kits are available from chemical supplier (e.g. Merck, Fluka).
  Suppliers: Varian, Unicam, Shimadzu, Perkin Elmer, Thermo Scientific, Analytik Jena *(Prize (€): 2 - 15'000)*
  Alternative Methods: Ion chromatography; Ion selective electrode

- **ICP spectrometer for trace element determination (8)**

  ICP-OES spectrometry has very low detection limits for trace elements and is preferred to AAS spectrometry for routine analysis. Emission relevant heavy metals (Hg, Tl and Cd) may pose problems due to low concentrations and due to the relatively poor sensitivity of the instrument for those elements. For Hg a hydride generator might be considered which improves also accuracy for other hydride forming elements (As, Sn, Se, Sb). Alternatively, dedicated Hg analyzer exists (see below). If Tl and Cd need to be accurately determined, an AAS spectrometer might be required.

  ICP-OES offers the possibility to simultaneously analyze a range of trace elements. It can also be used to quantify major elements (ash composition). However only liquid and clear solutions can be analyzed, thus complete digestion (24) of the sample is required, which is time consuming.
  The ICP excitation source coupled with a mass spectrometer (ICP-MS) offers extremely low detection limits but requires high skills and efforts in method development and even in daily routine work – besides high investment and maintenance costs. Investment in an ICP-MS needs to be evaluated very carefully and should be considered for specific applications only.

Suppliers: Perkin-Elmer, Varian, Horiba Jobin-Yvon, Spectro, Thermo Jarrell-Ash *(Prize (€):* 80-100'000)
Alternative Method: ED-XRF (see below)

- **ED-XRF spectrometer for trace element determination (8)**

  The ED-XRF technology has improved significantly over the last 20 years. Significant improvement was achieved by the introduction of polarized excitation. Compared to the traditional WD-XRF technology (used for cement analysis), ED-XRF spectrometers are more robust, cheaper to purchase and cheaper to operate and to maintain. Using standard-less software packages such as Turboquant or UniQuant completely unknown samples can be analyzed for trace elements (heavy metals). Little time is needed for sample preparation. Samples can be pressed to tablets (binding wax) or directly analyzed (solid, liquid or pasty).

  Depending on limit of detection and accuracy needed, several detection systems are available:

  - Proportional counter (cheap but low performance; used for portable systems, not in laboratories)
  - Semi-conductor based (PIN diode, Xflash drift chamber; mid-price and performance, used in bench-top analyzers)
  - Si(Li) detector (Requires liquid nitrogen cooling; High performance and price, comparable to WD-XRF systems)

  Suppliers: Panalytical (MiniPal series), Spectro, Thermo Scientific (ARL), Oxford Instruments, Shimadzu (Prize (€): 50-120’000)
  Remark:

  The ICP-OES equipment for determination of trace elements is still the state-of-the-art and widely applied in the Holcim Group. However, HGRS tested the bench-top EDXRF analyzer (Spectro), which is cheaper, faster and easier to handle and does not require a microwave furnace for sample preparation. The tests performed showed good results. Although the accuracy is lower than that of ICP, it is considered sufficient for routine income control at a plant laboratory. Nevertheless, periodic verification of the results with a reference method (ICP-OES) is recommended. Since several years, an EDXRF system (Spectro X-Lab 2000 with Si(Li) detector) is successfully in operation at the AFR pre-treatment platform in Belgium.

- **Mercury (Hg) analyzer (9)**

  Mercury has to be controlled accurately even at very low concentrations – especially in alternative raw materials (e.g. sewage sludge). A dedicated Hg analyzer based on AAS principle offers a superior alternative to conventional AAS or ICP-OES due to its excellent sensitivity. Limit of detection is in the region of 5 ppb. Solid samples can be measured directly without sample dissolution. It is not recommended to analyze flammable substances.
  Suppliers: Leco, Analytik Jena (AMA-254) *(Prize (€):*25'000)
  Alternative method: ICP-OES with hydrogen generator.

- **Kjeldahl Apparatus for the determination of Nitrogen (10)**

  Used to determine the total nitrogen content of a digested sample. Fully automatic units for a speedy and problem-free nitrogen determination are available, performing distillation, titration and calculation (mostly used for AR materials). For combustibles an elemental analyzer can be used, which works with the principle of the C/S analyzer (see above; Example TruSpec analyzer from LECO).

  Suppliers: Büchi, Gerhardt, Hamilton*, (Prize (€): 5`000)*

  Alternative methods: Ion-chromatography, UV/VIS using N specific test kits (Merck)

- **Gas chromatography for Organics and PCB (11-13)**

  The choice of the detector system depends largely on the application. It is possible to have more than one detector in one system and they can even be operated in parallel.

  - An electron capture detector (ECD) is recommended for PCB analysis or analysis of other chlorinated hydrocarbons. *(Prize (€): 25- 30`000)*
  - A flame ionization detector (FID) can be used for qualitative and comparative screening purposes only. It does not allow the identification of unknown substances. *(Prize (€): 20 - 25`000)*
  - A gas chromatograph with mass selective detector (MSD) (GC-MS) is recommended for qualitative identification and quantitative determination of unknown organic components. Quadrupole mass analyzers (sometimes in combination with an ion trap) are frequently used, since they are flexible and reasonably priced. Other systems such sector field analyzers or time-of flight analyzers (TOF) exist but are only recommended for special applications. MS systems operate under high vacuum and require trained staff and clean laboratory environment.

  Depending on the daily sample throughput, an auto-sampler might be advisable. Headspace systems allow analysis of volatile organic compounds directly from solid samples.

  Suppliers: Agilent (formerly HP), Varian, Perkin-Elmer (Prize (€): 80-150`000)

- **Apparatus for Chemical compatibility (14)**

  Whenever different wastes are mixed on a large scale (e.g. liquid substitution fuels), it must be assured that no chemical reactions between the wastes can occur.

  The compatibility test can be realized using a magnetic stirrer and standard glassware from chemical supply. Temperature, optical changes (fumes, layering, polymerization, colour changes, etc.) and gas evolution/pressure should be monitored.

  Suppliers: IKA, Metrohm (magnetic stirrer); Prize (€): 500-1’500, glassware < 200 €

- **Bomb calorimeter; Determination of calorific value (15)**
  Standard for determination of the calorific value of fuels is by combustion in bomb calorimeters. Different adiabatic or isoperbol systems are available with different degrees of automation (manual or semi-automatic). Depending on the number of daily samples an appropriate system should be chosen.
  Suppliers: IKA, Parr (Prize (€): 15-25`000)

- **Flash point analyzer; Determination of flash point (16)**

  Flash point can be measured with 'open cup' or 'closed cup' tester. Closed cup testers are closer to most situations, where (storage) space is confined. They give a lower (safer), more precise result and are less affected by laboratory conditions than closed cup testers. Open cup tester try to simulate open storage or spillage conditions. Closed-cup testers are required for liquids with flash points lower than room temperature (e.g. solvents; cooling system, required).

  There are several closed cup test methods (Pensky-Martens, Abel, Tag, Small Scale) according to national and international standards. The Small Scale test is standard according to the European Waste Directive and is recommended for waste materials. Local regulations may however demand other methods.
  For routine testing a 'flash/no flash' decision at the temperature of interest is sufficient. Exact flashpoint determination (manual or automatic) is usually not required. In case of high sample throughput, it may be useful to install two instruments (with heated and cooled cups) for low and high flash point measurement. For very alkaline samples, a corrosion resistant sample chamber (not Al) should be installed.
  Suppliers: Stanhope-Seta, Herzog, Petrotest *(Prize (€): 2'000 (manual)-10`000(automatic))*

- **pH-Meter; Determination of pH-Value (17)**

  This analyzer is available as analog model or as electronic instrument. It could also be included in a titrator system (see 1-3), thus just the pH-electrode needs to be purchased. Universal indicator paper from chemical suppliers (Merck, Fluka, etc) is often sufficient for routine testing
  Suppliers: Mettler-Toledo, Metrohm, Corning, Orion *(Prize (€): 1'000-2'000)*

- **Densimeter; Determination of density (18)**

  The measuring principle is a hollow glass tube that vibrates at a certain frequency. This frequency changes when the tube is filled with the sample: the higher the mass of the sample, the lower the frequency. This frequency is measured and converted into density. Bench-top instruments are equipped with a built-in Peltier thermostat to control the temperature (no water bath required).
  Suppliers: Mettler-Toledo, Metrohm *(Prize (€): 2'000-5'000)*
  Alternative methods: Pycnometer (for liquids), waster displacement method (solids)

- **Viscosimeter; Determination of viscosity (19)**

  Different manual and digital analyzers are available, most of them working according to the Brookfield standard.
  Suppliers: Anton Paar, Brookfield, Thermo Scientific (Haake) *(Prize (€): 2'000-5'000)*

- **Scintillometer; Determination of radioactivity (20)**

  Portable radiation counters (Geiger counter) or scintillation counters designed for field measurements are in most cases sufficient for control of radioactive substances.

  For pre-treatment platforms handling high waste volumes, a stationary measuring installation may be considered
  Suppliers: Beckmann, Berthold, Raytest (Prize (€): 2'000, stationary installation up to 50'000)

- **Muffle Furnace; Determination of ash content (21), ash preparation**

  Muffle furnaces for ash preparation usually operate in a temperature range from 100 to 1100°C. Ash preparation of AFR materials is potentially dangerous since toxic/noxious fumes can form during the heating. Therefore, excellent ventilation of the area (fume hood) must be provided.

  Suppliers: Nabertherm, Thermo Scientific, Neytech (Prize (€): 2'000 – 8'000)

  Alternative Method: Ash determination with combustion bomb (14)

- **Moisture Analyzer (22)**

  The analyzers determine quickly and effectively moisture in solid materials with halogen-heating technology (temperature range up to 200°C) and precision weighing. Also fluid bed dryer can be used (e.g. for RDF or fluff type fuels). The analyzers should not be use for materials which contain high amount of volatile organics (e.g. impregnated saw dust). They are suitable for biomass fuels.
  Suppliers: Ohaus, Mettler-Toledo, Retsch (Prize (€): 2'000)

Auxiliaries (24-31)

- **Sample Digestion, Microwave Furnace:**

  A microwave system is required for rapid sample digestion (or extraction) – mainly for trace element analyses with ICP or AAS.
  Systems with closed pressure vessels (usually made of Teflon) are more effective in achieving complete sample dissolution, but may bear a risk of developing overpressure with some organic materials (risk of bursting).
  Open microwave systems are cheaper and more rapid, but do not always assure complete dissolution of the sample.
  Suppliers: Prolabo, Milestone, CEM *(Prize (€): 15' - 25`000)*

- **Laboratory mills; sample preparation**

  For solid mineral matter, a small planetary ball mill or a disc swing mill is required for size reduction.
  For plastics, rubber, paper or solid biomass, a rotating knife mill or cryogenic mill is recommended. For plastics and rubber type materials freezing with liquid nitrogen and/or dry ice may be required to make the material brittle.
  Depending on the size of the material, a shredder (cutting mill) could help to reduce the material to a sufficient size for the different mills.
  To receive an excellent analytic result good mill equipment is a necessity!
  Suppliers: Retsch, Fritsch, Herzog, Spex *(Prize (€): 8'000 - 10`000)*

- **Balances**

  Balances of different capacity and precision must be available. Balances should be checked and calibrated regularly by the supplier (service contract).
  Suppliers: Mettler-Toledo, Sartorius, Scaltec, Ohaus *(Prize (€): 2'000 - 4`000)*

- **Water purification system**

  In addition to distilled or demineralized water, a specific water purification system is required in order to have suprapure water available for clean-up procedures in chromatography and metals analyses etc. This shall avoid any risk of cross-contamination.
  Suppliers: Millipore, Semat (Prize (€): ca. 3`000)

- **Evaporator, Centrifuge, Ultrasonic Bath**
  Evaporator: Suppliers: Buechi, Heidolph, Savant, Prize (€): ca. 2`000)
  Centrifuge: Suppliers: Sigma, Gallenkamp, Joua (Prize (€): ca. 2`000)
  Ultrasonic Bath: Suppliers: Branson, Fritsch, Semat (Prize (€): ca. 2`000)

- **Fume Hood**

  Working with hazardous wastes makes the use of fume hoods mandatory (safety reasons). Every AFR laboratory should have installed at least one fume hood by default.

  Suppliers: see supplier of laboratory furnace

5.3 Standard Operating Procedures

Written work instructions (Standard Operating Procedures, SOP's) must be available for each test carried out in the AFR control scheme, including sampling, sample storage, sample preparation, laboratory equipment management (calibration schedule, maintenance records, corrective actions in case of failures etc.) and validation of results.

The SOP's must be known and accessible for everybody in the laboratory. They are part of the ISO certification 14000/14001.

SOP's should refer to national or international standards (DIN, ASTM, etc) where available and/or where required in the permits.

Where standardized methods are not available or not practicable due to time constraints (for example in acceptance controls), the SOP must be validated, i.e. it must be demonstrated that the method is suitable to obtain correct results compared to a reference method.

A selection of useful ASTM Standard Methods is filed in *Annex 4*. For Standards see:

www.iso.org	(International Organization for Standardization)
www.cen.eu	(European Committee for Standardization)
www.astm.org	(American Society for Testing and Materials)

The ASTM organization has also published guidelines to set up procedures for waste management:

Under the CEN several technical committees (TC) have released a series of guidelines and standards related to waste management and testing. An overview of published standards from these committees is given also given in *Annex 4*.

- CEN/TC 292: Characterization of Waste
- CEN/TC 335: Solid Biofuels
- CEN/TCTC 343: Solid Recovered Fuels (that is high calorific, shredded fractions of industrial, commercial and municipal waste)

If there are still problems for setting up procedures, HGRS/CTS-MT can provide SOP's were it is required.

5.4 Data Recording and Processing

All laboratory data generated (from waste qualification tests, acceptance control, in pre-treatment platforms also process and product control) should be stored in an electronic database and – in addition – on paper copies. Home-made or commercial products can be used.

Writing access to the database should be restricted to a defined number of registered persons. The common measures to prevent access to the database by unauthorized persons have to be taken.

In principle, data entries should not be changed later. In rare cases, modification of data entries may be allowed to authorized persons only - for example, the laboratory manager. Any modification must be registered automatically by the system.

A well-designed electronic database system is a prerequisite for the regular evaluation of customers and contract reviews.

- Purpose of the AFR Database:
  - Recording and archiving of test results
  - Assuring traceability of test results
  - Generation of laboratory reports and charts
  - Administration of master data files of waste types
  - Statistical evaluations (fluctuations, customers etc.)
  - Data transfer to clients (cement plants, waste customers, authorities).

- Statistical data processing should provide "filter functions" for:
  - Individual waste types received
  - Individual customers of (untreated) wastes
  - In case of pre-treatment: Different AFR categories produced
  - Test types and test parameters
  - Time periods evaluated (annual, monthly, weekly statistics etc.).

It is strongly recommended to integrate the AFR laboratory database into the group company-wide data management, often referred to as LIMS (Laboratory Information and Management System). An example is the ABB LIMS system which is in operation now in many plants of the Holcim group. This system connected to a TIS (Technical Information System) gives easy and rapid data access and transfer on all levels.

5.5 Laboratory Design

The abilities of an AFR laboratory are clearly different from those of a traditional cement plant laboratory. The AFR laboratory must meet the standards of the chemical industries (Health & Safety).

Due to cost reasons, possible shortages in personnel, restrictions in available space and limited use of AFR materials, it should be considered to extend the existing cement laboratories in the plants with the necessary equipment.

Recommendations with regard to design and infrastructure of an AFR laboratory (in the cement plant or at a platform) are given in the following checklist. The AFR laboratory should have/be

- Separated physically, organizationally and budgetary from the regular cement plant laboratory if both installations are on the same site.
- Situated on the ground floor to ensure easy access of the laboratory personnel for sampling.
- Sufficient space to install the necessary equipment with options for future extension to facilitate increased AFR activities. Sufficient space between work places of personnel (> 1.5 m) to facilitate easy access and movement.
- Open architecture of the laboratory to facilitate communication and visual contact between the laboratory assistants. The office of the laboratory manager should have an open view to the laboratory.
- Separate room for sample reception and sample preparation (close to the analytical laboratory) with separate access for the sampler and a wall flap to the outside for sample receipt.
- Separate rooms for storage of chemicals and reference waste/AFR samples with adequate air ventilation system, shelves resistant against aggressive chemicals, sealed floors and appropriate fire detection/fighting.
- In case of a stand-alone laboratory: Provide for restrooms, sanitary installations, toilets etc.

- Doors opening to the outside for escape reasons. Swinging doors with safety glass are recommended.
- Standard safety installations and guidelines (fire extinguishers, eye flushes, safety showers, first aid kit, gloves, glasses, proper labeling etc.).
- An adequate dedusting system in the sample preparation room.
- Adequate service installations (water, gas, power, compressed air, vacuum etc.) with sufficient ports (taps, plugs etc.) on each laboratory desk.
- Storage of gas supply (pressurized bottles) outside of the laboratory.
- Air conditioning (note: may interfere with exhaust ventilation). Adequate ventilation and exhaust system in the whole laboratory. Hot air exhausts system for ICP/microwave installation and muffle furnaces.
- Sufficient (fixed) fume hoods (ICP, microwave system, sample clean-up for gas chromatography, acid extractions etc.) equipped with active carbon filters (to collect organic vapors).
- An acid neutralization system (mainly for vapors from microwave evaporation system).
- Ceramic (or glass-ceramic) table covers resistant against chemical and mechanical attack (acids, solvents etc.).
- Integrated balances in the work area with stabilized tables (stone plates, shock absorbers, rubber layers).
- A collecting system (labeled containers) for return of spent chemicals and samples to the process.
- Short descriptions of individual laboratory equipment for visitors (recommended).
- A central computer terminal for data entry.
- A central information board in the laboratory (delivery scheduling/ sample info etc.).
- In case of a new building: The AFR laboratory should be close to the truck receiving station with open view to the AFR installations (and to the truck receiving station, if possible).

Standard layouts of AFR laboratories are available at HGRS/CMS-MT, for an example and suppliers of laboratory furniture see *Annex 4*.

6. PERSONNEL REQUIREMENTS

6.1 Introduction

An AFR laboratory must be operated with well-trained personnel. For that reason HGRS/CMS-MT lists in this chapter the requirements for laboratory personnel. In general the AFR laboratory should have:

- A well-defined organization
- Work instructions (SOP's) for analytical tests and sampling
- H & S instructions for the laboratory work and sampling
- Training plans and training records for personnel

6.2 Requirements for Laboratory Managers

- Education in chemistry (university degree and/or long experiences in the field; profound knowledge of organic and analytic chemistry)
- Good knowledge of the technical process (AFR treatment installation, cement manufacturing)
- Good knowledge of the commercial aspects in the waste market (regular meetings)
- Good knowledge of environmental and H & S legislation
- Intensive training in H & S aspects (laboratory, technical installations)
- Specific certification for work with hazardous/toxic compounds (sometimes required by regulation)
- Language skills

6.3 Requirements for Laboratory Staff

- Basic education in chemistry (certified laboratory assistants)
- Internal analytical training on the job
- Training on H & S aspects (with regular updates)
- Knowledge on toxic properties of the waste and on the technical installations
- Sampling personnel:
  - Specific training in sampling techniques
  - Specific training in H & S aspects during sampling

6.4 Training Program

For all employers working in the AFR laboratory a training program should be undertaken. An outline for a training program is available at HGRS/MT. It takes around 4 weeks time to accomplish the program.

In case a new AFR organization is implemented the training program can be carried out in regional "reference centers" such as:

- Geocycle Seneffe/Obourg (Belgium) for Western Europe and North America
- Geocycle Albox/Holcim Spain for Southern Europe
- Ecorec/Holcim Slovensko (Slovak Republic) for Central/Eastern Europe
- Ecoblend/Grupo Minetti (Argentina) for Latin America

or at Holcim Group Support laboratories (for analytical procedures only). In case of training requests, please contact HGRS/CMS-MT.

The following list contains a basic training program with the priority on practical training:

- General:
  - Policies, general structure and responsibilities of the AFR organization
  - Waste and AFR quality control system
  - Administrative procedures (sample identification, labeling, formats)
  - Documentation and reporting system
  - Non-compliance procedures and responsibilities
- Health & safety training (more information and detailed instructions are in the Occupational AFR H&S manual by HGRS/Corporate OH&S):
  - General H & S plan (written work instructions, inspection/operating protocols)
  - H & S documentation and data recording
  - Learning and understanding of emergency response plans
  - Sound knowledge and understanding of toxic characteristics of waste categories
  - Use of personal protective clothing and equipment (during sampling and laboratory work)
  - Personal hygiene after shift work
- Overview on technical installations (receiving stations, storage/handling systems, blending/treatment installations, liquids tanks, dispatch, feeding to the kiln)
- Analytical Methods:
  - Waste sampling methods
  - Sample pre-treatment
  - Chemical tests
  - Physical tests
  - Calibration and verification procedures
  - Maintenance of the equipment
  - Sample storage and disposal

List of Acronyms

AAS	Atomic Absorption Spectroscopy
ASTM	American Society for Testing and Materials
DIN	German Institute for Standardization
ECD	Electron-Capture Detector
ED-XRF	Energy Dispersive X-ray Fluorescence
EMR	Emission Monitoring and Reporting
EN	European Norm
EPA	Environmental Protection Agency
FID	Flame Ionization Detector
FTIR	Fourier Transform Infrared Spectroscopy
GC	Gas Chromatography
GCD	Gas Chromatography Detector
HARP	Holcim Accounting and Reporting Principles
HGRS/CIE	**H**olcim **Gr**oup **S**upport / **C**orporate **I**ndustrial **E**cology
H & S	Health and Safety
ICP	Inductively Coupled Plasma
IPCC	International Panel for Climate Changes
KF	Karl-Fischer
LIMS	Laboratory Information and Management System
MS	Mass Spectrometer
MSD	Mass Selective Detector
MSDS	Material Safety Data Sheets
OES	Optical Emissions Spectroscopy
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyls
PE	Polyethylene
PTFE	Polytetrafluoroethylene
SOP	Standard Operating Procedure
TIS	Technical Information System
TOC	Total Organic Carbon
UV	Ultraviolet Spectroscopy
VIS	Visible Spectroscopy
VOC	Volatile Organic Compounds
WD-XRF	Wavelength Dispersive X-ray Fluorescence Spectroscopy

Literature:

Useful documents about AFR:

- Holcim Portal: The Community of Practice (CoP) on AFR Application
- Guidelines on co-processing Waste Materials in Cement Production (By the GTZ-Holcim Public Private Partnership, available on http://www.holcim.com/gc/CORP/uploads/GuidelinesCOPROCEM_web.pdf)
- Use of Alternative Fuels and Raw Materials (and citation therein), TPT 03/21206/E (available on Holcim Portal)
- Low Grade Fuel Study (TPT-07/21578)
- Guidelines for Alternative Raw Material (AR) Utilization, Rev. 2 (CMS-TPT 06/21413/E/Rev. 2)

Sampling:

- Gy, P: Sampling for Analytical Purpose. Wiley: New York 1998 Book
- Pitard, FF.: Pierre Gy's Sampling Theory and Sampling Practice (2nd. Edn.). CRC Press: Boca Raton, FL, USA, 1993
- RCRA Waste Sampling Draft Technical Guide, Planning, Implementation and Assessment, 2002, EPA-D-02-002, Document available on www.epa.gov/osw

General Waste Management:

- CD-ROM: ASTM Vol. 11.04, September 2003 Environmental Assessment; Hazardous Substances and Oil Spill Responses; Waste Management; Environmental Risk Management: www.astm.org
- Scoribel: Database: Quality System Documents, Scoribel S.A:Documentation on Holcim Portal

Standards:

- www.iso.org
- www.astm.org
- www.cen.eu

Annex 1

- ❑ List of fossil fuels according to IPCC (Intergovernmental Panel on Climate Change)
- ❑ AFR codification list according to HGRS-CIE

Table 1.2 Default net calorific values (NCVs) and lower and upper limits of the 95% confidence intervals [1]				
Fuel type English description		**Net calorific value (TJ/Gg)**	**Lower**	**Upper**
Crude Oil		42.3	40.1	44.8
Orimulsion		27.5	27.5	28.3
Natural Gas Liquids		44.2	40.9	46.9
Gasoline	Motor Gasoline	44.3	42.5	44.8
	Aviation Gasoline	44.3	42.5	44.8
	Jet Gasoline	44.3	42.5	44.8
Jet Kerosene		44.1	42.0	45.0
Other Kerosene		43.8	42.4	45.2
Shale Oil		38.1	32.1	45.2
Gas/Diesel Oil		43.0	41.4	43.3
Residual Fuel Oil		40.4	39.8	41.7
Liquefied Petroleum Gases		47.3	44.8	52.2
Ethane		46.4	44.9	48.8
Naphtha		44.5	41.8	46.5
Bitumen		40.2	33.5	41.2
Lubricants		40.2	33.5	42.3
Petroleum Coke		32.5	29.7	41.9
Refinery Feedstocks		43.0	36.3	46.4
Other Oil	Refinery Gas [2]	49.5	47.5	50.6
	Paraffin Waxes	40.2	33.7	48.2
	White Spirit and SBP	40.2	33.7	48.2
	Other Petroleum Products	40.2	33.7	48.2
Anthracite		26.7	21.6	32.2
Coking Coal		28.2	24.0	31.0
Other Bituminous Coal		25.8	19.9	30.5
Sub-Bituminous Coal		18.9	11.5	26.0
Lignite		11.9	5.50	21.6
Oil Shale and Tar Sands		8.9	7.1	11.1
Brown Coal Briquettes		20.7	15.1	32.0
Patent Fuel		20.7	15.1	32.0
Coke	Coke Oven Coke and Lignite Coke	28.2	25.1	30.2
	Gas Coke	28.2	25.1	30.2
Coal Tar [3]		28.0	14.1	55.0
Derived Gases	Gas Works Gas [4]	38.7	19.6	77.0
	Coke Oven Gas [5]	38.7	19.6	77.0
	Blast Furnace Gas [6]	2.47	1.20	5.00
	Oxygen Steel Furnace Gas [7]	7.06	3.80	15.0
Natural Gas		48.0	46.5	50.4

AFR And Traditional Fuel Classification							
			PCS [ii] Code			CO2 [iii] Categories	Remarks
Group[i]	Family	Class	Group	Family	Class		
Raw Materials Semi-Finished / Finished Products	Raw Materials Semi-Finished / Finished Products		01	00	00		
	Traditional calcareus components		01	01	00		
	...		...	...	...		
	Traditional iron-rich components		01	04	00		
	Alternative Raw Materials	Alternative raw materials	01	05	00		
		Aluminous corrective	01	05	01	-	
		Granulated blast furnace slag	01	05	13	-	only if used for clinker production not as MIC
		Non-granulated blast furnace slag	01	05	14	-	only if used for clinker production not as MIC
		Bottom ash	01	05	03	-	only if used for clinker production not as MIC
		Calcareous corrective	01	05	04	-	
		Contaminated soils	01	05	05	-	
		Ferrous corrective	01	05	06	-	
		Fly ash	01	05	07	-	only if used for clinker production not as MIC
		Fluor provider (mineralizer)	01	05	08	-	
		Other raw mix correctives	01	05	09	-	
		Other slags	01	05	10	-	only if used for clinker production not as MIC
		Sulfur provider	01	05	11	-	
		Siliceous corrective	01	05	12	-	
		Other alternative raw materials	01	05	99	-	
Energy / Fuels	Energy / Fuels		02	00	00		
	Traditional Fuels						
	Traditional Solid Fuels	Traditional solid fuels	02	01	00		
		Coal, antracite, bituminous coal	02	01	01	1	
		Petcoke	02	01	02	2	
		lignite	02	01	03	6a	
		shale	02	01	04	6	
		other solid traditional fuels	02	01	99	1	incl. waste coal, waste coke, graphite
	Traditional Liquid Fuels	Traditional liquid fuels	02	02	00		
		Fuel Oils - SHFO, HFO, MFO	02	02	01	3	
		Fuel Oils - LFO (inlcuding Diesel/Gasoil)	02	02	02	4	
		Gasoline	02	02	03	7	
		Bitumen	02	02	04	-	
		Other Liquid traditional fuels	02	02	99	-	
	Traditional Gaseous Fuels	Traditional gaseous fuels	02	03	00		
		Natural Gas	02	03	01	5	
		Other Gaseous traditional fuels	02	03	99	5	
	Alternative Fuels						
	Alternative biomass fuels	Alternative biomass fuels	02	04	00		
		Agricultural wastes	02	04	11	20	including outdated (shelf life) material
		Animal meal	02	04	12	17	The WBCSD Cement CO2 Protocol further divides "Animal meal" into "Animal bone meal" and "Animal meal". Holcim uses a combined category.
		Animal fat	02	04	19	19	
		Biogas	02	04	13	21	
		Charcoal	02	04	14	20	
		Paper / cardboard residues / diapers	02	04	15	16	
		Sewage sludge	02	04	16	14	
		Wood residues	02	04	17	15	
		Sawdust (impregnation material)	02	04	20	- or 15	This is not meant to be burned - this is raw material for the platform to produce impregnated sawdust for co-processing; only if sawdust is used as untreated fuel category 15 applies
		Other biomass	02	04	99	21	
	Alternative fossil fuels Gas	Alternative fossil fuels gas	02	09	00		
		Other fossil gas	02	09	01	13	
	Alternative fossil fuels Liquids	Alternative fossil fuels liquid	02	06	00		
		Distillation residues	02	06	01	13	
		Emulsions	02	06	02	13 or -	If emulsion HHV >8 GJ/t, then category 13 applies; if emulsion HHV < 8 GJ/t, CO2 emissions are not calculated
		Polluted waste waters	02	06	03	-	CO2 emissions are not calculated for polluted waste water
		Prepared liquid substitution fuel	02	06	04	13	A liquid derived from a specific pre-blending activity, either from a pre-treater, from the AFR platform or the cement plant, e.g. synfuel, etc.
		Solvents (non-chlorinated)	02	06	05	11	< 1% Cl
		Solvents (chlorinated)	02	06	06	11	> 1% Cl
		Pharmaceutical waste liquid	02	06	07	13	e.g. out of spec medicine, outdated medicine, etc.
		High viscosity liquids	02	06	08	13	High Viscosity Liquids (HVL) only used in Holcim US, < 1000 cp up to 30% of solids, can be atomized in main burner.
		Used / waste oils	02	06	09	8	
		Liquid waste for external treatment	02	06	10	-	waste to be redirected to external solution
		Other liquid wastes	02	06	99	13	
	Alternative fossil fuels - Pasty	Alternative fossil fuels pasty	02	07	00		
		Petroleum sludges	02	07	01	13	Including petroleum based tank bottom oil
		Other sludges	02	07	02	13	
		Drilling muds	02	07	03	13	
		Other pasty wastes	02	07	99	13	
	Alternative fossil fuels Solid	Alternative fossil fuels solid	02	08	00		
		Bituminous residues / tar	02	08	01	13	
		Fullers earth	02	08	02	13	
		Plastics coarse	02	08	03	10	foils (2D particles) < 200 mm 3D, spherical particles < 50 mm
		Plastics fine	02	08	04	10	foils (2D particles) < 50 mm 3D, spherical particles < 5 mm
		Impregnated substitution fuel coarse	02	08	05	12 or 12a	If only saw dust is used for impregnation, then category 12 applies, otherwise 12a has to be used
		Impregnated substitution fuel fine	02	08	06	12 or 12a	If only saw dust is used for impregnation, then category 12 applies, otherwise 12a has to be used
		Other prepared solid substitution fuels	02	08	07	12a	
		Other impregnation material	02	08	08	-	Other impregnation material than sawdust - only considered a raw material for the production of impregnated substitution fuel
		TDI residues	02	08	09	13	Toluene-Di-Isocyanate
		Tires, shredded	02	08	10	9	
		Tires, whole	02	08	11	9	
		Textile waste	02	08	12	13	
		Pharmaceutical waste solid	02	08	13	13	e.g. out of spec medicine, outdated medicine, etc.
		Resins	02	08	14	13	
		Fluff	02	08	15	13	includes RDF(refuse derived fuel) and SRF (solid recovered fuel) form municipal waste
		Solid waste for external treatment	02	08	16	-	waste to be redirected to external solution
		Other solid wastes coarse	02	08	98	13	foils (2D particles) < 200 mm 3D, spherical particles < 50 mm
		Other solid wastes fine	02	08	99	13	foils (2D particles) < 50 mm 3D, spherical particles < 5 mm

Annex 2

- ❑ Waste Identification File

- ❑ Incoming Analytical Control file

- ❑ Example of a procedure for incoming waste

Waste Identification File [page 1]

Waste codification (national)				Codification according to Holcim			
Potential (and/or)		☐ AR	☐ AF				
Source				User			
waste generator	☐	platform	☐	plant	☐	platform	☐
Company				Company			
Adress				Adress			
Contact				Contact			
Phone				Phone			
Fax				Fax			
E-mail				E-mail			
AFR / Waste generating process							
Principal constituents		Chemical formula		Minimum		Average	Maximum
				%		%	%
				%		%	%
				%		%	%
				%		%	%
				%		%	%
AFR / Waste availability							
from process	☐	t / year		Expected duration			
storage capacity				spot ☐	> 1 year ☐	< 1 year ☐	
from stock	☐	stock	t	cost / t			
AFR / Waste delivery							
Timing of delivery		Transport					
Continous over the year	☐	Rail ☐		Drums ☐		Tank truck ☐	
Irregular / seasonal	☐	Big bag ☐		IBC ☐		Bulk truck ☐	
Macroscopic properties							
solid ☐	Max. particle size / mm			Dust generation	high	☐ ☐ ☐	low
	>100 ☐	10 - 1 ☐		Foreign bodies	frequent	☐ ☐ ☐	none
	100 - 10 ☐	< 1 ☐		Flowability	high	☐ ☐ ☐	low
	homogeneous	☐ yes	☐ no	Stickiness	high	☐ ☐ ☐	low
sludge ☐	homogeneous	☐ yes	☐ no	Stickiness	high	☐ ☐ ☐	low
				Foreign bodies	frequent	☐ ☐ ☐	none
liquid ☐	aqueous ☐	organic ☐		Viscosity	high	☐ ☐ ☐	low
	Different phases	☐		Particles	much	☐ ☐ ☐	none
				Sedimentation	strong	☐ ☐ ☐	weak
Other characteristics							
Color	dark	☐ ☐ ☐	light	Odor	strong	☐ ☐ ☐	no
Banned wastes - not allowed as per AFR-policy							
Anatomical hospital wastes		☐ yes	☐ no	Explosives		☐ yes	☐ no
Asbestos-containing wastes		☐ yes	☐ no	High-concentration cyanide wastes		☐ yes	☐ no
Bio-hazardous wastes		☐ yes	☐ no	Mineral acids		☐ yes	☐ no
Electronic scrap		☐ yes	☐ no	Radioactive wastes		☐ yes	☐ no
Entire batteries		☐ yes	☐ no	Unsorted municipal garbage		☐ yes	☐ no

Waste Identification File [page 2]

Holcim	AFR / WASTE PROFILE 2 of 4			CHEMICAL & PHYSICAL PROPERTIES	
Designation			Industry of origin		

Analytical laboratory		Information source			
Company		Date			
Adress		Sample information			
		one spot sample	☐	Composite sample	☐
Contact		taken by			
Phone	Fax	Comments			
Email					

Physical and chemical properties

	Min.	Average	Max.		Min.	Average	Max.
H_2O content as delivered %				Boiling point °C			
Viscosity Pa				Melting point °C			
Density kg / m^3				Residue on ....mm %			
Bulk density kg / m^3				Residue on ....mm %			
pH				Residue on ....mm %			
Water soluble compounds							

Organic properties

Sample preparation	air dried	☐	dried	☐	other		
	Sample Average	estimated Min.	Max.		Sample Average	estimated Min.	Max.
Ash content %				S %			
Volatiles content %				C %			
CV gross MJ / kg				H %			
CV net MJ / kg				PCB ppm			
Flash point °C				PCT ppm			
TOC %				Phenols ppm			

Inorganic properties

Sample preparation		air dried	☐	dried	☐	other			
Mineral components		Min.	Average	Max.			Min.	Average	Max.
Quartz %					Other				
Main oxides	L. o. i. %				Trace elements	Cd ppm			
	SiO_2 %					Hg ppm			
	Al_2O_3 %					Tl ppm			
	Fe_2O_3 %					As ppm			
	CaO %					Ni ppm			
	MgO %					Co ppm			
	SO_3 %					Se ppm			
	K_2O %					Te ppm			
	Na_2O %					Cu ppm			
	TiO_2 %					Pb ppm			
	Mn_2O_3 %					Sb ppm			
	P_2O_5 %					Sn ppm			
Halogenes, others	F %					V ppm			
	Cl %					Be ppm			
	Br %					Ba ppm			
	I %					Mn ppm			
	CN %					Zn ppm			
	NH_3 %					Cr ppm			

Waste Identification File [page 3]

Holcim	AFR / WASTE PROFILE 3 of 4				HEALTH & SAFETY
Designation			Industry of origin		
Material safety data sheet					
available	☐	not available	☐		
Hazards identification					
Inflammable	☐	Irritant	☐	By eye contact	☐
Corrosive	☐	Harmful	☐	By skin contact	☐
Reactive	☐	Toxic	☐	By inhalation	☐
Respirable	☐	Carcinogen	☐	By ingestion	☐
Risk of hazardous reactions					
with ↓ \ to →	Toxic vapour	Ignition	Explosion	Polymerisation	Solidification
High temperature	☐	☐	☐	☐	☐
High pressure	☐	☐	☐	☐	☐
Water	☐	☐	☐	☐	☐
Air	☐	☐	☐	☐	☐
Acids	☐	☐	☐	☐	☐
Bases	☐	☐	☐	☐	☐
Oxidants	☐	☐	☐	☐	☐
Reductants	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐
Comments					

Personal protection					
Acid resistant clothes	☐	Safety helmet	☐	Safty gloves	☐
Full protection mask	☐	Safty glasses	☐	Semi-protection mask	☐

First aid	
Appropriate measures	
Inappropriate measures	
Fire instruction	
Appropriate measures	
Inappropriate measures	
Specific risks / instructions	
Spill instructions	
Clean-up procedures	
Recovery procedures	
Disposal procedures	
Contact in urgent cases	

Transport					
Hasard code		Transport code		Waste code	
Comments					

Waste Identification File [page 3]

Holcim	AFR / WASTE PROFILE				4 of 4	PLANT HANDLING & APPLICATION	
Designation				Industry of origin			
Classification (see ATR)				HGRS-Code (see ATR)			
Actual amount consumed		t / year		t / h (average)		t / h (max.)	
Pretreatment							
drying	☐	grinding	☐	screening	☐	shredding	☐
mixing	☐	other:					
Comments							
Storage							
open storage	☐	covered storage	☐	sealed floor	☐	non-sealed floor	☐
Bunker	☐	Silo	☐	Tank	☐	Pit	☐
drums	☐	big bag	☐	IBC	☐	Moving floor cont.	☐
other:				Storage capacity:			
Comments							
Extraction from storage							
Front end loader	☐	Live bottom feeder	☐	Aeration	☐	Mechanical outlet activation	☐
Crane	☐	Reclaimer	☐	other:			
Comments							
Transport from storage to process							
Front end loader	☐	Crane	☐	Chain conveyor	☐	Bucket elevator	☐
Hydraulic	☐	Pump type:		Screw conveyor	☐	Belt conveyor	☐
Pneumatic	☐			other:			
Comments							
Dosing							
gravimetric	☐			volumetric	☐		
Belt scale	☐	Impact flowmeter	☐	Rotary valve	☐	Belt feeder	☐
Lossweight feeder	☐	Coriolis flowmeter	☐	Positive Displace-ment Pump	☐	Screw feeder	☐
Rotor weigh feeder	☐	other:				other:	
Comments							
Feed to process							
Raw mat. crusher	☐	Raw mill	☐	Preheater	☐	Kiln inlet	☐
Preblending bed	☐	Slurry mill	☐	Lepol grate	☐	Mid kiln	☐
Slurry basin	☐	Coal mill	☐	Calciner	☐	Next to main flame	☐
other:						Main burner	☐
Comments							
Quality control							
Comments							
Limiting factors for utilisation							
Market availability	☐	Handling problems	☐	Feeding capacity	☐	Cost	☐
Main oxides	☐	Chlorids	☐	Trace elements	☐	Toxicity	☐
Water content	☐	Permits	☐	other:			

Incoming Analytical Control File

Holcim	Shipment Control Analysis	Version 001
	1 of 1	

Designation		Industry of origin	
Analytical laboratory		**Information source**	
Company		Date	
Adress		Sample information	
		one spot sample ☐	Composite sample ☐
Contact		taken by	
Phone	Fax	Comments	

Physical and chemical properties

	Result		Result		Result
H_2O content as delivered %		Boiling point °C		Ash content %	
Viscosity Pa		Melting point °C		Volatiles content %	
Density kg / m^3		Residue on ....mm %		CV gross MJ / kg	
Bulk density kg / m^3		Residue on ....mm %		CV net MJ / kg	
pH		Residue on ....mm %		Flash point °C	
Water soluble compounds					
Sample preparation	air dried ☐	dried ☐	other		

	Result		Result
PCB ppm		S %	
PCT ppm		C %	
Phenols ppm		H %	
TOC %			

Main oxides	L. o. i.	%				Trace elements	Cd	ppm			
	SiO_2	%					Hg	ppm			
	Al_2O_3	%					Tl	ppm			
	Fe_2O_3	%					As	ppm			
	CaO	%					Ni	ppm			
	MgO	%					Co	ppm			
	SO_3	%					Se	ppm			
	K_2O	%					Te	ppm			
	Na_2O	%					Cu	ppm			
	TiO_2	%					Pb	ppm			
	Mn_2O_3	%					Sb	ppm			
	P_2O_5	%					Sn	ppm			
Halogenes, others	F	%					V	ppm			
	Cl	%					Be	ppm			
	Br	%					Ba	ppm			
	I	%					Mn	ppm			
	CN	%					Zn	ppm			
	NH_3	%					Cr	ppm			

Comments or observations:

Approved by:		Visa		Date	
Approved by:		Visa		Date	

Example of a procedure for incoming waste

No.	WHO		WHAT
	Responsibilities	Authorities	
1	Driver Planning Co-ordinator		When the lorry arrives at the Scoribel site, it goes for weighing. The driver gives the Planning Co-ordinator his documents.
2	Planning Co-ordinator		The Planning Co-ordinator checks whether the lorry was expected or not.
3	Planning Co-ordinator		If not, he/she checks whether it was scheduled in under another chronological number.
4	Planning Co-ordinator		If it was, he/she contacts the customer to find out whether this is the product announced in the driver's documents or the one scheduled. In the former case, the procedure moves on to stage 7.
5	Customer		If it is the scheduled product, the customer faxes the relevant documents.
6	Planning Co-ordinator		If the lorry is not scheduled either under the number shown on the driver's documents or under another chronological number, the Planning Co-ordinator checks if the driver holds the necessary documents.
7		Platform Production Supervisor Laboratory Supervisor	If it is, the Planning Co-ordinator contacts the Platform Production Supervisor and the Laboratory Supervisor to obtain their agreement to taking on the delivery.

No.	WHO		WHAT
	Responsibilities	Authorities	
8	Planning Co-ordinator		If one of them does not agree to taking on the load for various reasons (LEI00018 *'Decision to reject waste delivery'*), the Planning Co-ordinator informs the Customer. He/she then starts procedure EXP00010 *'Notification of Scoribel delivery refusals to the Walloon Region'*
9	Planning Co-ordinator		If the various parties agree to taking the delivery, the Planning Co-ordinator notifies the customer and asks him to schedule all deliveries to the site in future. The procedure moves on to stage 17.
10	Planning Co-ordinator		If the lorry is not scheduled and the driver does not have the necessary documents, the Planning Co-ordinator contacts the client to find out what the product is and if the delivery was intended for Scoribel. If it was, he/she checks with the Sales Department whether the acceptance dossier has been validated. If the delivery cannot be taken for any reason, (LEI00018 *'Waste delivery rejection decision'*), the Planning Co-ordinator starts procedure EXP00010 *'Notification of Scoribel delivery refusals to the Walloon Region'*.
11		Platform Production Supervisor Laboratory Supervisor Legal Manager	If the product is intended for Scoribel and everything is in order at commercial level, the Planning Co-ordinator contacts the Platform Production Supervisor and the Laboratory Supervisor as well as the Legal Manager if the waste comes from abroad, in order to obtain their agreement to the delivery being taken. Otherwise (LEI00018 *'Waste delivery rejection decision')*, the Planning Co-ordinator starts procedure EXP00010 *'Notification of Scoribel delivery refusals to the Walloon Region'*.

No.	WHO		WHAT
	Responsibilities	Authorities	
12	Planning Co-ordinator Customer		If the various parties agree to taking the delivery, the Planning Co-ordinator notifies the customer and asks him to schedule all deliveries to the site in future. When we have the right documents, the procedure carries on from stage 17.
13	Planning Co-ordinator		If the lorry is scheduled, the Planning Co-ordinator checks whether the driver has the necessary documents. EXI00005 *'Necessary documents - Scoribel deliveries'*
14			If not, does the product come from abroad?
15		Legal Manager	If so, the Planning Co-ordinator contacts the Legal Manager to obtain his/her agreement to the client faxing the documents (if DTT, the original by post or with the next delivery) and to the delivery being accepted. If he does not agree (LEI00018 *'Waste delivery rejection decision')*, the Planning Co-ordinator starts procedure EXP00010 *'Notification of Scoribel delivery refusals to the Walloon Region'*.
16	Planning Co-ordinator		If the Legal Manager agrees or if the producer is not foreign, the Planning Co-ordinator asks the customer to fax through the missing documents.
17	Planning Co-ordinator		When he/she has the necessary documents, the Planning Co-ordinator checks according to the type of product whether the carrier needs to be approved in the Walloon Region or not. If not, the procedure moves on to stage 20.

No.	WHO		WHAT
	Responsibilities	Authorities	
18	Planning Co-ordinator		If it does, he/she checks on the basis of document LER00044 *'List of carriers approved in the Walloon Region'* whether the company carrying out the transport is approved.
19	Planning Co-ordinator		If not he/she informs the Walloon Region by fax.
20	Planning Co-ordinator		When everything is in order, the Planning Co-ordinator fills in part of Form EXF00001 *'Unloading monitoring sheet - loose'* or EXF00026 *'Unloading monitoring sheet – containers'* and enters the weighing. EXI00005 *'Reception weighing of incoming products'*
21	Planning Co-ordinator		The Planning Co-ordinator gives the driver document SHR00002 *'Driver safety instructions'* which he/she must sign to show that he/she has examined it.
22			Is this a loose delivery? If so, the procedure moves on to stage 52.
23	Planning Co-ordinator		If the delivery is in containers, the Planning Co-ordinator gives the driver document EXF00026 'Unloading monitoring sheet – containers' filled in at stage 20.
24	Drums Handler		Before unloading, the drums handler checks the condition of the containers and the palettes.
25	Drums Handler		If there is a problem, he/she informs the foreman, who informs the Platform Production Supervisor.

Annex 3

- Waste/ AFR specifications from different Group Companies

AFR Specifications by Countries						
	Unit	Germany Median Value [1)] [at 20 MJ/Kg]	Median Value [2)] [at 16 MJ/kg]	Switzerland AF [3)] [at 25 MJ/kg]	Wastes for Solid AF Prep. [4)]	AR [5)]
Ag	**ppm**	**--**	**--**	**5**	**5**	**--**
As	**ppm**	**5**	**5**	**15**	**15**	**20**
Be	**ppm**	**0.5**	**0.5**	**5**	**3**	**3**
Cd	**ppm**	**4**	**4**	**2**	**10**	**0.8**
Co	**ppm**	**6**	**6**	**20**	**20**	**30**
Cr	**ppm**	**40**	**125**	**100**	**400**	**100**
Cu	**ppm**	**120**	**350**	**100**	**500**	**100**
Hg	**ppm**	**0.6**	**0.6**	**0.5**	**0.5**	**0.5**
Mn	**ppm**	**50**	**250**	**--**	**--**	**--**
Ni	**ppm**	**25**	**80**	**100**	**300**	**100**
Pb	**ppm**	**70**	**190**	**200**	**600**	**50**
Sb	**ppm**	**25**	**25**	**5**	**5**	**1**
Se	**ppm**	**3**	**3**	**5**	**5**	**1**
Sn	**ppm**	**30**	**30**	**10**	**10**	**50**
Te	**ppm**	**3**	**3**	**--**	**--**	**--**
Tl	**ppm**	**1**	**1**	**3**	**3**	**1**
V	**ppm**	**10**	**10**	**100**	**100**	**200**
Zn	**ppm**	**--**	**--**	**400**	**4000**	**400**
PCB	**ppm**	**--**	**--**	**10**	**10**	**1**

1) Guide values for selected process wastes, referring to a net calorific value of 20 MJ/kg. All values based on dry matter. Statistical evaluation based on 10 samples.
2) Guide values for sorted domestic wastes, referring to a net calorific value of 16 MJ/kg. All values based on dry matter. Statistical evaluation based on 10 samples.
3) Guide Values for AF not included in the „Positive List“. For wastes listed in the „Positive List“, individual guide values apply. The guide values have to be adapted to the net calorific value.

4) Guide values for wastes accepted for the preparation of mixed solid fuels (i.e. impregnated sawdust).
5) Values based on dry matter.

		Yocsina	Apaxco	Holcim (Cesko) Prachovice		Holcim (France) Plant Obourg			ASO/Hirocem			Holcim (US)		
Properties	**Unit**	General Specification		Liquid AF	Solid AF	Liquid AF	Solid AF	Waste Water	ASO Permit	Internal (solid AF)	Internal (liquid AF)	Artesia	Clarksville	Holly Hill
CV	**MJ/kg**	--	> 17	> 35	> 15	> 17	--	--	--	> 13	> 38	> 23	> 25.5	> 25.5
Water	**%**	30/40	20	10	--	40	40	--	--	50	10	20	20	25
Solids	**%**	10	20	--	25	30	--	30	--	--	--	30	30	20
Flash Point		--	--	> 56	--	> - 10	> - 10	> 55	--	--	--	--	--	--
Ash	**%**	--	--	--	--	--	--	--	--	--	--	20	10	15
Viscosity	**cp**	--	--	--	--	700	--	700	--	--	--	600	125	125
pH		--	4 – 11	--	--	4-14	--	4-14	--	--	--	5 – 10	5 – 10	5 – 10
S	**%**	3	1	3	3	3	3	3	3	0.5	2	2	2	1.4
Cl	**%**	2	0.5	0.5	1.5	6	3	6	1.5	0.3	0.3	3	3.5	2.2
F	**%**	--	--	--	0.02	--	--	--	--	0.2	--	1	1	1
Halogens	**%**	--	--	--	--	0.2	0.2	0.2	--	--	--	--	--	--
CN	**ppm**	100	--	--	--	100	100	100	1000 (sol)	100	--	--	--	--
PCB	**ppm**	0	50	30	30	30	30	30	150	50	30	50	50	50
Ag	**ppm**	--	--	--	--	--	--	--	--	--	--	50000	105	2500
As	**ppm**	200	100	--	--	200	200	200	200	200	200	24	30	50
Ba	**ppm**	1000	--	--	--	--	--	--	1000	--	--	100000	3150	20000
Be	**ppm**	50	--	--	--	50	50	50	50	50	50	1.3	112	10
Cd	**ppm**	100	500	10	5	100	100	100	100	100	100	265	228	250
Co	**ppm**	200	--	--	--	200	200	200	200	200	200	--	--	--
Cr	**ppm**	1000	3000	--	--	1000	1000	1000	2500	700	700	800	1950	2500
Cu	**ppm**	--	--	--	--	1000	1000	1000	1000	1000	1000	--	--	--
Hg	**ppm**	10	50	2	1	10	10	10	5	5	5	1.8	21	50
Ni	**ppm**	1000	--	--	--	1000	1000	1000	1000	1000	1000	2500	2500	2500
Pb	**ppm**	1000	4000	--	--	1000	1000	1000	5000	1000	1000	2990	2800	2170
Sb	**ppm**	50	--	--	--	50	50	50	800	100	100	8000	525	1000
Se	**ppm**	100	--	--	--	50	50	50	50	--	--	2500	2500	2500
Tl	**ppm**	100	--	10	5	100	100	100	10	10	5	1000	105	22
V	**ppm**	1000	--	--	--	1000	1000	1000	3000	--	--	--	--	--
Zn	**ppm**	5000	--	4000	2000	5000	5000	5000	15000	5000	2000	7500	4000	5000
As+Ni+Cr+Co	**ppm**	--	--	200	100	--	--	--	--	--	--	--	--	--
Pb+Cu+W	**ppm**	--	--	2000	1000	--	--	--	--	--	--	--	--	--

Annex 4

- ❑ Waste/AFR test equipment
- ❑ Calibration standards for AFR testing
- ❑ List of suppliers (websites)
- ❑ SOP's for AFR quality control according to ASTM
- ❑ Published SOP's (EN) for waste, solid recovered fuels and biofuels
- ❑ Standard AFR laboratory layout and addresses of suppliers

Waste/AFR Test Equipment			
Test Parameter	**Equipment**	**Suppliers**	**Cost [€]**
Anions	UV-VIS Spectrophotometer	Varian, Unicam, Shimadzu	10 - 15'000
Ash/Volatiles Content	Muffle Furnace	Nabertherm, Linn, Lindberg, Solo, Carbolite	3'000
Calorific Value	Bomb Calorimeter	IKA, Parr	20 - 25'000
Carbon Content (RM)	Carbon Analyzer	Leco, Rosemount, Shimadzu	25 - 40'000
Cations/Anions	Ion Chromatograph	Dionex, Waters, Metrohm	35 - 40'000
Chlorine	Titrator + Electrode	Mettler, Metrohm, WTW, Orion	10'000
Density	Densimeter	Mettler, Corning, Beckman, Hitachi	2'500
Flash Point	Flash Point Analyzer (manual or autom)	Stan Hope, Herzog, Gallenkamp, Petrotest	2'000 - 10'000
Fluorine	Ion Meter + Ion-selective Electrode	Mettler, Metrohm, WTW, Orion	5'000
Heavy Metals	ICP Spectrometer	Perkin-Elmer, Varian, Jobin-Yvon, Spectro, Thermo Jarrell-Ash	70 - 90'000
	EDXRF Bench top Spectrometer	Philips, Spectro, Bruker, Oxford	50 - 70`000
Mercury	AA Spectrometer	Leco/Altec	25'000
Moisture Content	Drying Oven	WTB, Heraeus, Salvis, Memmert, Ohaus	3'000
Nitrogen	Kjeldahl Distillator	Büchi, Gerhardt, Hamilton	5'000
Organic Compounds	Gas Chromatograph (FID)	Agilent, Varian, Perkin-Elmer	20 - 25'000
Organic Compounds	Gas Chromatograph (MSD)	Agilent, Varian, Perkin-Elmer	80 - 90'000
PCB's	Gas Chromatograph (ECD)	Agilent, Varian, Perkin-Elmer	25 - 30'000
pH - Value	pH Meter	Mettler, Metrohm, Corning, Orion	1'000
Radioactivity	Scintillometer	Beckman, Berthold, Raytest	2'000
Sulfur	Sulfur Analyzer	Leco, Jobin-Yvon, Shimadzu, Antek	25 - 40'000
Sample Digestion	Microwave Furnace	Prolabo, Milestone, CEM	15 - 25'000
Viscosity	Viscosimeter	Brookfield, Haake, Contraves, Anton Paar	4'000
Water Content	Karl-Fischer-Apparatus	Mettler, Metrohm, Orion	8'000
Auxiliaries	Laboratory Mill	Retsch, Fritsch, Herzog, Spex	8 - 10'000
Auxiliaries	Balances	Mettler, Sartorius, Scaltec, Ohaus	2'000 - 4'000
Auxiliaries	Ultrasonic Bath	Branson, Fritsch, Semat	2'000
Auxiliaries	Suprapure Water System	Millipore, Semat	3'000
Auxiliaries	Evaporator	Buechi, Heidolph, Savant	2'000-8'000
		Sum:	500`000 €

Calibration Standards for AFR Testing

Test Parameter	Equipment	Standards	Supplier
PCB's	Gas Chromatograph	Ballschmiter-Standards (6 PCB's) Aroclor Standards (1242, 1248, 1254, 1260, 1262, 1268) Chlophen Standards (A28, A30, A40, A50, A60) Aroclor (15 PCB's)	Riedel-de Haën, Merck, Agilent, Supelco, Promochem, NIST AccuStandard
Heavy Metals	ICP	Multi-Element Standards (in HNO_3) Single-Element Standards (in HNO_3) SRM 1633 (Fly Ash) SRM 2711 (Montana Soil) BCR 143R (Sewage Sludge/Soil) CRM 018-050 (Sewage Sludge) SRM 1634 (Fuel Oil)	Merck, Aldrich-Sigma, Alfa-Aesar, Johnson-Matthey, Riedel-de Haën NIST NIST BCR RTC NIST
Chlorine, Sulfur	Titration	Chemicals (P.A.) SRM 1619-1624 (S in Fuel Oil) AR 3505 (S and Cl in Oil)	Merck, Aldrich etc. NIST Labtech
Calorific Value	Calorimeter	Benzoic Acid SRM 39 (Benzoic Acid) SRM 2683, 2684, 2692 (Coal) CRM 065 (Coal)	IKA, Parr NIST NIST BCR
Water Content	KF Apparatus	Disodium tartrate dihydrate	Merck
Flash Point	Flash Point Analyzer	Iso-Octane (low FP) n-Decane (high FP)	NIST, BCR
Viscosity	Viscosimeter	Standard Solutions (var. cps) PSL N10, N100, N350 etc.	Brookfield PSL

List of Suppliers Website Address:

Supplier	Website Address	Supplier	Website Address
Agilent (former HP)	www.agilent.com	Metrohm	www.metrohm.ch
Alfa Aesar	www.alfa.com	Mettler-Toledo	www.mt.com
Antek	www.antekhou.com	Milestone	www.milestonesci.com
Beckman	www.beckmancoulter.com	Millipore	www.millipore.com
Branson	www.bransoncleaning.com	Nabertherm	www.nabertherm.com
Brookfield	www.brookfieldengineering.com	NIST	www.nist.gov/srm
Buechi	www.buchi.com	Ohaus	www.ohaus.com
Carbolite	www.carbolite.com	Orion	www.orionres.com
CEM	www.cem.com	Parr	www.parrinst.com
Corning	www.corning.com	Perkin Elmer	www.perkin-elmer.com
Fisher-Rosemount	www.frco.com/fr	Petrotest	www.petrotest.com
Fritsch	www.fritsch.de	Promochem	www.radian.com
Gallenkamp	www.sanyogallenkamp.com	Raytest	www.raytest.de
Gerhardt	www.gerhardt.de	Retsch	www.acornsci.com/retsch
Haake	www.haake.de	Sartorius	www.iescorp.com
Hamilton	www.hamiltoncompany.com	Shimadzu	www.shimadzu.com
Heidolph	www.heidolph.com	Sigma-Aldrich	www.sigma-aldrich.com
Heraeus	www.heraeus-noblelight.com	Spectro	www.spectro-ai.com
Hosokawa (Alpine)	www.hosokawamicron.com	Spex	www.spexcsp.com
IKA	www.ika.net	Thermo Jarrell-Ash	www.tja.com
Jobin-Yvon	www.jyemission.com	Unicam	www.unicam.co.uk
Leco	www.leco.com	Varian	www.varianinc.com
Lindberg	www.lindberght.com	Waters	www.waters.com
Linn	www.linn.de	WTB-Binder	www.wtb-binder.com
Memmert	www.memmert.com		-
Merck	www.merck.com		-

List of ASTM Standard Methods:

Parameter	Reference	Title
CV, Ash Content	ASTM D 5468-95	Standard Test Method for Gross Calorific and Ash Value of Waste Materials
Halogens, Sulfur	SW 846 9056	Determination of Inorganic Anions by Ion Chromatography Method
PCB‘s	ASTM D 6160-98	Standard Test Method for Determination of PCB’s in Waste
PCB‘s	ASTM D 4059	Standard Test Method for Determination of PCB’s in Oil
pH	ASTM D 4980-89 SW 846 9045	Standard Test Method for Screening of pH in Waste
Digestion	ASTM E 926-94	Standard Practice for Preparing Refuse-Derived Fuel Samples for Analysis of Metals
Metals	SW 846 6010 A	Inductively Coupled Plasma-Atomic Emission Spectroscopy
Density	ASTM D 5057-90	Standard Test Method for Screening Apparent Specific Gravity and Bulk Density of Waste
Viscosity	ASTM D 2196-99	Standard Test Method for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscosimeter
Water Content	ASTM E 203-96	Standard Test Method for Water Using Karl-Fischer Titration
Cyanides	ASTM D 5049-90	Standard Test Method for Screening of Cyanides in Waste
Sulfides	ASTM D 4978-95	Standard Test Method for Screening of Reactive Sulfides in Waste
VOC/SVOC	GCI Method	A Method for the Rapid Semi-Quantitative Identification of Hazardous Organic Constituents in Liquid Organic Hazardous Waste Streams
VOC (in solids)	SW 846 8260	Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)
Organics	ASTM D 5830	Standard Test Method for Solvent Analysis in Hazardous Waste Using Gas Chromatography
Radioactivity	ASTM D 5928-96	Standard Test Method for Screening of Waste for Radioactivity
Compatibility/ Reactivity	ASTM D 5058-90	Standard Test Method for Compatibility of Screening Analysis of Waste

CEN/TC 292: Characterization of waste: Published Standards

Standard reference	Title
CEN/TR 14589:2003	Characterization of waste - State of the art document - Chromium VI specification in solid matrices
CEN/TR 15018:2005	Characterization of waste - Digestion of waste samples using alkali-fusion techniques
CEN/TR 15310-1:2006	Characterization of waste - Sampling of waste materials - Part 1: Guidance on selection and application of criteria for sampling under various conditions
CEN/TR 15310-2:2006	Characterization of waste - Sampling of waste materials - Part 2: Guidance on sampling techniques
CEN/TR 15310-3:2006	Characterization of waste - Sampling of waste materials - Part 3: Guidance on procedures for sub-sampling in the field
CEN/TR 15310-4:2006	Characterization of waste - Sampling of waste materials - Part 4: Guidance on procedures for sample packaging, storage, preservation, transport and delivery
CEN/TR 15310-5:2006	Characterization of waste - Sampling of waste materials - Part 5: Guidance on the process of defining the sampling plan
CEN/TS 14405:2004	Characterization of waste - Leaching behavior tests - Up-flow percolation test (under specified conditions)
CEN/TS 14429:2005	Characterization of waste - Leaching behavior tests - Influence of pH on leaching with initial acid/base addition
CEN/TS 14997:2006	Characterization of waste - Leaching behavior tests - Influence of pH on leaching with continuous pH-control
CEN/TS 15364:2006	Characterization of waste - Leaching behavior tests - Acid and base neutralization capacity test
EN 12457-1:2002	Characterization of waste - Leaching - Compliance test for leaching of granular waste materials and sludges - Part 1: One stage batch test at a liquid to solid ratio of 2 l/kg for materials with high solid content and with particle size below 4 mm (without or with size reduction)
EN 12457-2:2002	Characterization of waste - Leaching - Compliance test for leaching of granular waste materials and sludges - Part 2: One stage batch test at a liquid to solid ratio of 10 l/kg for materials with particle size below 4 mm (without or with size reduction)
EN 12457-3:2002	Characterization of waste - Leaching - Compliance test for leaching of granular waste materials and sludges - Part 3: Two stage batch test at a liquid to solid ratio of 2 l/kg and 8 l/kg for materials with high solid content and with particle size below 4 mm (without or with size reduction)
EN 12457-4:2002	Characterization of waste - Leaching - Compliance test for leaching of granular waste materials and sludges - Part 4: One stage batch test at a liquid to solid ratio of 10 l/kg for materials with particle size below 10 mm (without or with size reduction)
EN 12506:2003	Characterization of waste - Analysis of eluates - Determination of pH, As, Ba, Cd, Cl-, Co, Cr, Cr VI, Cu, Mo, Ni, NO2-, Pb, total S, SO42-, V and Zn
EN 12920:2006	Characterization of waste - Methodology for the Determination of the Leaching Behavior of Waste under Specified Conditions
EN 13137:2001	Characterization of waste - Determination of total organic carbon (TOC) in waste, sludges and sediments
EN 13370:2003	Characterization of waste - Analysis of eluates - Determination of Ammonium, AOX, conductivity, Hg, phenol index, TOC, easily liberatable CN-, F-

Standard reference	Title
EN 13656:2002	Characterization of waste - Microwave assisted digestion with hydrofluoric (HF), nitric (HNO3) and hydrochloric (HCl) acid mixture for subsequent determination of elements
EN 13657:2002	Characterization of waste - Digestion for subsequent determination of aqua regia soluble portion of elements
EN 13965-1:2004	Characterization of waste - Terminology - Part 1: Material related terms and definitions
EN 13965-2:2004	Characterization of waste - Terminology - Part 2: Management related terms and definitions
EN 14039:2004	Characterization of waste - Determination of hydrocarbon content in the range of C10 to C40 by gas chromatography
EN 14345:2004	Characterization of waste - Determination of hydrocarbon content by gravimetry
EN 14346:2006	Characterization of waste - Calculation of dry matter by determination of dry residue or water content
EN 14582:2007	Characterization of waste - Halogen and sulfur content - Oxygen combustion in closed systems and determination methods
EN 14735:2005	Characterization of waste - Preparation of waste samples for ecotoxicity tests
EN 14735:2005/AC: 2006	Characterization of waste - Preparation of waste samples for ecotoxicity tests
EN 14899:2005	Characterization of waste - Sampling of waste materials - Framework for the preparation and application of a Sampling Plan
EN 15002:2006	Characterization of waste - Preparation of test portions from the laboratory sample
EN 15169:2007	Characterization of waste - Determination of loss on ignition in waste, sludge and sediments
EN 15192:2006	Characterization of waste and soil - Determination of Chromium(VI) in solid material by alkaline digestion and ion chromatography with spectrophotometric detection
EN 15216:2007	Characterization of waste - Determination of total dissolved solids (TDS) in water and eluates
EN 15308:2008	Characterization of waste - Determination of selected polychlorinated biphenyls (PCB) in solid waste by using capillary gas chromatography with electron capture or mass spectrometric detection
EN 15309:2007	Characterization of waste and soil - Determination of elemental composition by X-ray fluorescence

CEN/TC 343 – Solid Recovered Fuels: Published Standards

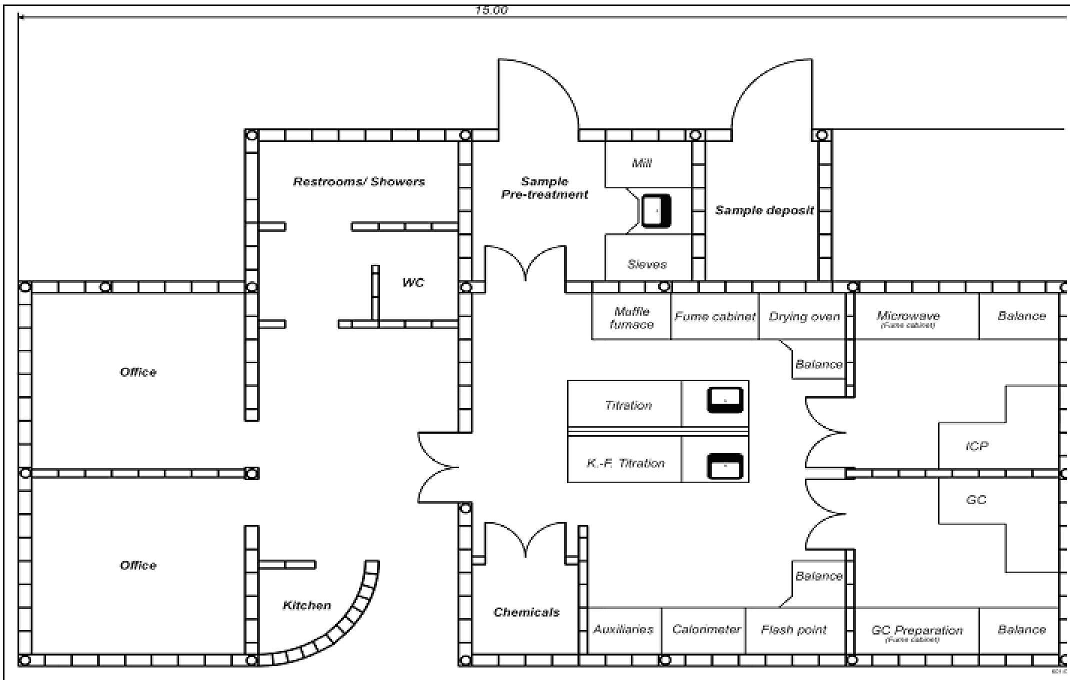
Standard reference	Title
CEN/TR 14980:2004	Solid recovered fuels - Report on relative difference between biodegradable and biogenic fractions of SRF
CEN/TR 15441:2006	Solid recovered fuels - Guidelines on occupational health aspects
CEN/TR 15508:2006	Key properties on solid recovered fuels to be used for establishing a classification system
CEN/TR 15591:2007	Solid recovered fuels - Determination of the biomass content based on the 14C method
CEN/TS 15357:2006	Solid recovered fuels - Terminology, definitions and descriptions
CEN/TS 15358:2006	Solid recovered fuels - Quality management systems - Particular requirements for their application to the production of solid recovered fuels
CEN/TS 15359:2006	Solid recovered fuels - Specifications and classes
CEN/TS 15400:2006	Solid recovered fuels - Methods for the determination of calorific value
CEN/TS 15401:2006	Solid recovered fuels - Methods for the determination of bulk density
CEN/TS 15402:2006	Solid recovered fuels - Methods for the determination of the content of volatile matter
CEN/TS 15403:2006	Solid recovered fuels - Methods for the determination of ash content
CEN/TS 15404:2006	Solid recovered fuels - Methods for the determination of ash melting behavior by using characteristic temperatures
CEN/TS 15405:2006	Solid recovered fuels - Methods for the determination of density of pellets and briquettes
CEN/TS 15406:2006	Solid recovered fuels - Methods for the determination of bridging properties of bulk material
CEN/TS 15407:2006	Solid recovered fuels - Method for the determination of carbon (C), hydrogen (H) and nitrogen (N) content
CEN/TS 15408:2006	Solid recovered fuels - Methods for the determination of sulfur (S), chlorine (Cl), fluorine (F) and bromine (Br) content
CEN/TS 15410:2006	Solid recovered fuels - Method for the determination of the content of major elements (Al, Ca, Fe, K, Mg, Na, P, Si, Ti)
CEN/TS 15411:2006	Solid recovered fuels - Methods for the determination of the content of trace elements (As, Ba, Be, Cd, Co, Cr, Cu, Hg, Mo, Mn, Ni, Pb, Sb, Se, Tl, V and Zn)
CEN/TS 15412:2006	Solid recovered fuels - Methods for the determination of metallic aluminum
CEN/TS 15413:2006	Solid recovered fuels - Methods for the preparation of the test sample from the laboratory sample
CEN/TS 15414-1:2006	Solid recovered fuels - Determination of moisture content using the oven dry method - Part 1: Determination of total moisture by a reference method
CEN/TS 15414-2:2006	Solid recovered fuels - Determination of moisture content using the oven dry method - Part 2: Determination of total moisture by a simplified method
CEN/TS 15414-3:2006	Solid recovered fuels - Determination of moisture content using the oven dry method - Part 3: Moisture in general analysis sample
CEN/TS 15415:2006	Solid recovered fuels - Determination of particle size distribution by screen method

Standard reference	Title
CEN/TS 15440:2006	Solid recovered fuels - Method for the determination of biomass content
CEN/TS 15442:2006	Solid recovered fuels - Methods for sampling
CEN/TS 15443:2006	Solid recovered fuels - Methods for laboratory sample preparation
CEN/TS 15590:2007	Solid recovered fuels - Determination of potential rate of microbial self heating using the real dynamic respiration index
CEN/TS 15639:2007	Solid recovered fuels - Methods for the determination of mechanical durability of pellets

EN/TC 355 Solid Biofuels: Published standards

Standard reference	Title
CEN/TS 14588:2003	Solid biofuels - Terminology, definitions and descriptions
CEN/TS 14774-1:2004	Solid biofuels - Methods for determination of moisture content - Oven dry method - Part 1: Total moisture - Reference method
CEN/TS 14774-2:2004	Solid biofuels - Methods for the determination of moisture content - Oven dry method - Part 2: Total moisture - Simplified method
CEN/TS 14774-3:2004	Solid biofuels - Methods for the determination of moisture content - Oven dry method - Part 3: Moisture in general analysis sample
CEN/TS 14775:2004	Solid biofuels - Method for the determination of ash content
CEN/TS 14778-1:2005	Solid biofuels - Sampling - Part 1: Methods for sampling
CEN/TS 14778-2:2005	Solid biofuels - Sampling - Part 2: Methods for sampling particulate material transported in lorries
CEN/TS 14779:2005	Solid biofuels - Sampling - Methods for preparing sampling plans and sampling certificates
CEN/TS 14780:2005	Solid biofuels - Methods for sample preparation
CEN/TS 14918:2005	Solid Biofuels - Method for the determination of calorific value
CEN/TS 14961:2005	Solid biofuels - Fuel specifications and classes
CEN/TS 15103:2005	Solid biofuels - Methods for the determination of bulk density
CEN/TS 15104:2005	Solid biofuels - Determination of total content of carbon, hydrogen and nitrogen - Instrumental methods
CEN/TS 15105:2005	Solid biofuels - Methods for determination of the water soluble content of chloride, sodium and potassium
CEN/TS 15148:2005	Solid biofuels - Method for the determination of the content of volatile matter
CEN/TS 15149-1:2006	Solid biofuels - Methods for the determination of particle size distribution - Part 1: Oscillating screen method using sieve apertures of 3,15 mm and above
CEN/TS 15149-2:2006	Solid biofuels - Methods for the determination of particle size distribution - Part 2: Vibrating screen method using sieve apertures of 3,15 mm and below
CEN/TS 15149-3:2006	Solid biofuels - Methods for the determination of particle size distribution - Part 3: Rotary screen method
CEN/TS 15150:2005	Solid biofuels - Methods for the determination of particle density
CEN/TS 15210-1:2005	Solid biofuels - Methods for the determination of mechanical durability of pellets and briquettes - Part 1: Pellets
CEN/TS 15210-2:2005	Solid biofuels - Methods for the determination of mechanical durability of pellets and briquettes - Part 2: Briquettes
CEN/TS 15234:2006	Solid biofuels - Fuel quality assurance
CEN/TS 15289:2006	Solid Biofuels - Determination of total content of sulfur and chlorine
CEN/TS 15290:2006	Solid Biofuels - Determination of major elements
CEN/TS 15296:2006	Solid Biofuels - Calculation of analyses to different bases
CEN/TS 15297:2006	Solid Biofuels - Determination of minor elements
CEN/TS 15370-1:2006	Solid biofuels - Method for the determination of ash melting behavior - Part 1: Characteristic temperatures method

Standard Laboratory Layout



Standard Laboratory Layout

Suppliers of Laboratory furniture:

For general laboratory furniture:
E. Renggli AG
Industrie-Ost
CH-6343 Rotkeuz
Switzerland
www.renggli.ch

Waldner
Laboreinrichtungen
D-88229 Wangen
Germany
www.waldner.de