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## Foreword

This document is a working document.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex A, B, C or D, which is an integral part of this document.

This standard is applicable and validated for several types of matrices. The table below indicates which ones.

| <b>Material</b> | <b>Validated for</b><br><b>(type of sample, e.g. municipal sludge, compost)</b>                                   | <b>Document</b>    |
|-----------------|---|--------------------|
| Sludge          | Municipal sludge, Industrial sludge, sludge from electronic industry, ink waste sludge                            | EN 13346, EN 13657 |
| Soil            |   |                    |
| Soil improvers  | Partly validated (thermal heating), e.g. biowaste, composted sludge   | EN 13650           |
| Sediment        |   |                    |
| Waste           | City waste incineration fly ash, city waste incineration bottom ash, ink waste sludge, electronic industry sludge | EN 13657           |

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## Introduction

This document is developed in the project 'Horizontal'. It is the result of a desk study "Digestion of Solid Matrices" and aims at evaluation of the latest developments in assessing digestion of sludge, soil, treated biowaste and neighbouring fields. After discussion with all parties concerned in CEN and selection of a number of test methods described in this study the standard has been developed further as an modular horizontal method and has been validated within in the project 'Horizontal'.

A horizontal modular approach is being investigated and developed in the project 'Horizontal'. 'Horizontal' means that the methods can be used for a wide range of materials and products with certain properties. 'Modular' means that a test standard developed in this approach concerns a specific step in a test procedure and not the whole test procedure (from sampling to analyses).

The use of modular horizontal standards implies the drawing of test schemes as well. Before executing a test on a certain material or product to determine certain characteristics it is necessary to draw up a protocol in which the adequate modules are selected and together form the basis for the test procedure.

This standard is a module, for analysis of inorganic parameters in solid matrices. This module concerns the digestion with aqua regia for the subsequent analysis of elements.

This document is a horizontal draft standard composed of parts of the following existing standards:

- ISO 11466 Soil quality – Extraction of trace elements soluble in aqua regia
- EN 13346 Characterization of sludges Determination of trace elements and phosphorus Aqua regia extraction methods
- EN 13650 Soil improvers and growing media – Extraction of aqua regia soluble elements
- EN 13657 Characterization of waste - Digestion for subsequent determination of aqua regia soluble portion of elements

The horizontal draft standard was prepared by comparing the different paragraphs of the standards for digestion with aqua regia and trying to look for equivalence and find a compromise where differences were obvious. In some cases differences were necessary because of the different matrices – this is pointed out in the specific paragraphs.

The other horizontal modules that will be available in due time are to be found in the informative annex [xxx] which contains a brief overview of the modules that will be worked out in the project 'Horizontal.'

The texts of the chapters 1 to 12 are normative; annexes are normative or informative, as stated in the top lines of the annexes.

## 1 Scope

This European Standard describes methods of digestion with aqua regia of the following materials: Soil, sludge, biowaste and waste. Solutions produced by the methods are suitable for analysis e.g. by atomic absorption spectrometry (FLAAS, HGAAS, CVAAS, GFAAS), inductively coupled plasma emission spectrometry (ICP-OES) and inductive coupled plasma mass spectrometry (ICP-MS).

The digestion with aqua regia is empirical and will not necessarily release all elements completely. However for most environmental applications the results are fit for the purpose.

## 2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN ISO 3696: 1997, *Water for analytical laboratory use - Specification and test methods*.

EN xxx *Determination of Dry matter (HORIZONTAL)*

EN *Determination of TOC (HORIZONTAL)*

EN *Sampling (HORIZONTAL)*

EN *Sample pre-treatment (HORIZONTAL)*

## 3 Terms and definitions

For the purpose of this European Standard, the following definitions apply:

### 3.1 aqua regia

digestion solution obtained by mixing 1 volume of nitric acid (65 - 70 % m/m) and 3 volumes of hydrochloric acid (35 - 37 % m/m).

### 3.2 digestion

mineralization of the organic matter of a sample and dissolution of its mineral part, more or less completely, when reacted with a reagent mixture.

### 3.3 sample

portion of material selected from a larger quantity of material

### 3.4 laboratory sample

sample or sub sample(s) sent to or received by the laboratory

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### **3.5 test sample; analytical sample**

### **3.6 sample, prepared from the laboratory sample, from which test portions are removed for testing or analysis test portion; analytical portion**

quantity of material of proper size for measurement of the concentration or other properties of interest, removed from the test sample

NOTE 1: The test portion may be taken from the laboratory sample directly if no preparation of sample is required (e. g. with liquids), but usually it is taken from the prepared test sample.

NOTE 2: A unit or increment of proper homogeneity, size and fineness, needing no further preparation, may be a test portion.

### **3.7 dry matter**

the remaining mass fraction of a sample after the specified drying process. It is expressed in percentage or as grams per kilogram (EN XXXXX:200X – horizontal standard).

### **3.8 digestion vessel**

special flask where the test portion and the acid mixture are filled in and the digestion is performed.

### **3.9 microwave unit**

is the whole microwave digestion system (oven and associated equipment).

### **3.10 microwave unit cavity**

the inner part of the microwave unit in which the digestion vessel is located and the microwave digestion is performed.

### **3.11 focused microwave unit**

NOTE: Microwaves are focused at the bottom part of the digestion vessel.

## **4 Safety remarks**

All this work has to be performed by skilled persons.

The reagents used within this EN are strongly corrosive and partly very toxic. Safety precautions are absolutely necessary due to strong corrosive reagents, high temperature and high pressure.

All procedures have to be performed in a hood or in closed force-ventilated equipment. By the use of strong oxidising reagents the formation of explosive organic intermediates is possible especially when dealing with samples with a high organic content. Do not open pressurised vessels before they have cooled down. Avoid contact with the chemicals and the gaseous reaction products. Samples and solutions have to be disposed of according to regulations.

## 5 Principle

The laboratory sample is prepared in order to obtain a representative test portion which is extracted with aqua regia according to one of the following heating procedures:

- boiling for about 2 h with a reflux condenser, followed by filtration and making up to volume in a volumetric flask (method A) ;
- microwave digestion for about 20 min in a closed vessel followed by filtration and making up to volume in a volumetric flask (method B) ;

NOTE: Other heating procedures can be used providing they demonstrate equivalent performance.

## 6 Interferences and sources of errors

### 6.1 General information

Due to the volatility of some compounds it is of great importance to take care, that the sample is not heated before the digestion and that the volatile reaction products which might be formed during the digestion are not allowed to escape.

The container in which the sample is delivered and stored can be a source of errors. Its material shall be chosen according to the elements to be determined (e.g. elemental Hg can penetrate polyethylene walls very fast in both directions. Glass can contaminate samples with elements contained: e.g. B, Na, K, Al).

Grinding or milling samples includes a risk of contamination of the sample by the environment (air, dust, wear of milling equipment). Due to elevated temperature losses of volatile compounds are possible.

For the determination of elements forming volatile compounds (e.g. Hg, As, Pb) special care has to be taken at sample pre-treatment.

The use of the described digestion procedures may leave large parts of the sample undissolved. This includes the risk of bad repeatability.

High acid and solute concentrations in the digest may cause interferences at determination.

Depending on the concentration of the element of interest and the wanted precision, a particular caution to the cleaning of the vessels shall be taken. It is recommended to clean the vessels by cooking them with aqua regia or 10 % nitric acid.

Care shall be taken to ensure that all of the test portion is brought into contact with the acid mixture in the reaction vessel.

Some elements of interest can be lost because of precipitation with some ions of the solution. It is the case for insoluble chlorides, fluorides and sulphates for example. In this case the precipitate can be analysed separately.

In the case of filtration of the digested solution it is necessary to take care that the filtration procedure does not introduce contaminants.

### 6.2 Closed vessel system

The upper limits of mass of the test portion referring to the manufacturer's specifications have to be taken into account.

Very reactive or volatile materials that may create high pressures when heated may cause a venting of the vessels with potential loss of sample and analytes. The complete decomposition of either carbonates, or carbon based samples, may cause enough pressure to vent the vessel.

After digestion, the vessel shall be cooled to room temperature before opening. If not, losses of certain elements, particularly volatile elements as mercury or arsenic can occur.

## 7 Reagents

Use only reagents of recognised analytical grade and water grade 1 in accordance with ISO 3696.

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## 7.1 General

All reagents used shall be of recognized analytical quality. Use water of grade 2 complying with EN ISO 3696.

Deionised water may be used, providing that it meets the requirements given above. It is recommended that the same batch of water be used throughout a given batch of determinations and that blank determinations are carried out.

## 7.2 Water

Deionised or distilled water used shall conform to purity grade 2 of EN ISO 3696.

## 7.3 Hydrochloric acid

$c(\text{HCl}) = 12 \text{ mol/l}$ ;  $\rho = 1,18 \text{ g/ml}$ ; 37 % mass/volume

## 7.4 Nitric acid

$c(\text{HNO}_3) = 15 \text{ mol/l}$ ;  $\rho = 1,42 \text{ g/ml}$ ; not less than 65 % mass/volume

## 7.5 Nitric acid, diluted

$c(\text{HNO}_3) = 0,5 \text{ mol/l}$ , 35 ml nitric acid (5.4) is diluted to one litre of water

# 8 Apparatus

## 8.1 General

All glassware and plastic ware shall be adequately cleaned and stored in order to avoid any contamination.

NOTE Depending on the concentration of the element of interest, a particular caution to the cleaning of the vessels shall be taken. It is recommended to clean the vessels by cooking with aqua regia or with 10 % nitric acid.

## 8.2 Digestion vessel

Digestion vessel, temperature- and pressure-resistant and capable of containing the mixture of sample and digest solution. The inner wall of the vessel shall be inert and shall not release substances to the digest in excess of the purity requirements of the subsequent analysis.

Method A) glass flask, 250 ml for example;

Method B) quartz or teflon vessel (at least 100 ml) equipped with a system capable of controlling overpressure in order to avoid explosion of the vessel



NOTE1 Quartz vessels can be used instead of glass vessels.

NOTE2 It can be necessary to periodically clean the reaction vessels with a suitable surfactant to remove stubborn deposits.

### 8.3 Vapour recovery system

Vapour recovery system, capable of recovering the evaporated digest during open digestion (e.g. reflux condenser) and designed to minimise losses

Materials in contact with the vapour shall be inert and shall meet the purity requirements of the subsequent analysis

Adaptable to reaction vessels used in method A.

### 8.4 Absorption vessel

Volatile species trap, in an open digestion system capable of trapping one or more volatile measurement species, which may pass through the vapour recovery system (7.3).

### 8.5 Heating devices

Method A) a heating mantle or aluminium block heater;

Method B) a focused microwave oven with programmable power to control fast exothermic reaction.

### 8.6 Filter papers

Filter paper cellulose based, hardened and resistant to aqua regia.

### 8.7 Volumetric flasks

capacity 25 ml, 50 ml or 100 ml.

### 8.8 Analytical balance

with an accuracy of 0,1 mg or better.

### 8.9 Boiling aids

anti bumping granules or glass beads, diameter 2 mm to 3 mm, acid washed (for method A)

## 9 Sampling and sample pre-treatment

### 9.1 Sampling

Sampling should be carried out in accordance with EN yyyy:2003 (Horizontal standard module(s) for sampling of sludge, soil and waste).

Samples should be stored in suitable containers with an appropriate closure material. Samples should be kept cold (< 8°C). The sample pre-treatment should take place within 1 month of sampling. Alternatively, samples may be

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frozen (-18 °C) directly after sampling and kept frozen before sample pre-treatment.

## 9.2 Sample pre-treatment

### 9.3 Pre-treatment of test portion

The test portion should be transferred into the vessel after a pre-treatment of the laboratory sample to result in homogeneous and representative test portions out of the laboratory sample. This procedure shall not change the concentration of the elements of interest.

Pre-treatment should include drying or grain size reduction below a particle size of 250 µm for solid materials or homogenizing by use of pestle and mortar for dried sludges or a high speed mixer or sonification for liquid samples.

NOTE: For soil samples it is common to use the fraction < 2mm; if it is used without any particle size reduction, an influence of grain size on recovery rate of digestion cannot be excluded for some types of soil.

The mass of laboratory samples shall be sufficient for the multiple digestion procedures and determination of the dry matter.

### 9.4 Mass of test portion

The mass of test portion for a single digestion has to be selected in a way, that:

- it is representative for the laboratory sample
- it complies with the specifications of manufacturer of the digestion unit.

NOTE: If the representative test portion exceeds the manufacturer's specifications the test portion should be divided into smaller quantities and digested separately. The individual digests should be combined prior to analysis.

For representativity reason mass above 200 mg is to be preferred. Unless recommended by the manufacturer the amount of organic carbon shall not exceed 100 mg because of safety reasons in the case of closed digestion vessel.

## 10 Procedure

### 10.1 Blank test

The reagent blank test shall be carried out in parallel with the determination, by the same procedure, using the same quantities of all the reagents as in the determination but omitting the test portion.

NOTE The measurement of a blank is introduced to determine the contribution of the extracting solution, glassware and filter paper used.

### 10.2 Method A: Thermal heating under reflux conditions

#### 10.2.1 Amount of test portion

Weigh approximately 3 g, to the nearest 0,001 g, of the prepared sample (9) and transfer to the 250 ml reaction vessel (7.2).

NOTE: If necessary it is possible to weigh 1 g to 10 g of the prepared sample and transfer it to the reaction vessel. In this case the appropriate amount of acid mixture should be added to obtain a mass to volume ratio between sample and acid mixture of 1:10.

#### 10.2.2 Digestion

Moisten the sample with about 0,5 ml to 1,0 ml of water (6.2) and add, with mixing, 21 (± 0,1) ml of hydrochloric acid (6.3) followed by 7 (± 0,1) ml of nitric acid (6.4) drop wise if necessary to reduce foaming. Connect the condenser (7.3) to the reaction vessel; fill the absorption vessel (7.4) with aqua regia. Connect the absorption vessel to the

condenser, and let stand at room temperature until any effervescence almost ceases to allow for slow oxidation of the organic mass in the sample.

**NOTE** The time of standing at room temperature may have an influence on the digestion rate of aqua regia. For comparison reason of the method it is recommended to start heating as soon as possible after the first strong reaction has ceased.

30 ml of aqua regia is sufficient only for the oxidation of about 0,5 g organic carbon. If there is any doubt of the amount of carbon present, carry out a determination of TOC. If there is more than 0,5 g of organic carbon in the test portion, proceed as follows.

Allow first reaction with the aqua regia to subside. Then add an extra 1 ml of nitric acid only to every 0,1 g of organic carbon above 0,5 g. Do not add more than 10 ml of nitric acid at any time, and allow any reaction to subside before proceeding further.

Transfer to the heating device (7.5) and raise the temperature of the reaction mixture slowly to reflux conditions and maintain for 2 h ensuring that the condensation zone is lower than 1/3 of the height of the condenser, then allow to cool. Add the content of the adsorption vessel to the reaction vessel via the condenser, rinsing both the absorption vessel and condenser with further 10 ml of diluted nitric acid (6.5) or with 10 ml of water (6.2).

**NOTE:** If the digested sample contains particulates which can clog nebulisers or interfere with injection of the sample, the sample can be centrifuged, allowed to settle, or filtered before transferring into a suitable sized volumetric flask (7.7). For example, the solution should be allowed to pass through the filter paper (7.6), and then the insoluble residue washed onto the filter paper with a minimum of water (6.2). The method used has to be reported in the test report.

Transfer the digested sample into a suitable sized volumetric flask (7.7) and dilute to the mark with water (6.2).

## 10.3 Method B: Microwave assisted digestion in closed vessels

### 10.3.1 Amount of test portion

Weigh between 0,2 g to 0,5 g of the sample, accurately at 0,1 mg, prepared according to clause 9 and transfer it into the vessel (7.2).

### 10.3.2 Digestion

If necessary the sample may be moistened with a minimum amount of water (6.2). Then add separately 6 ml of HCl (6.3) and 2 ml of HNO<sub>3</sub> (6.4).

If a vigorous reaction occurs, allow the reaction to lie down before capping the vessel. Transfer the digestion vessels into the microwave oven (7.5) according to the manufactures instructions and start the following digestion procedure.

Table 1: Power programme

| Time (min) | Power (W) |
|------------|-----------|
| 2          | 250       |
| 2          | 0         |
| 5          | 250       |
| 5          | 400       |
| 5          | 500       |

The above power programme is intended to be used for batches of 6 samples. Commercial available microwave units may contain more or less sample positions. In order to ensure consistant reaction conditions in these cases the power

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programme has to be adjusted according to the manufactures instructions. For batches where all positions are not occupied either the empty positions shall be filled up with e.g. blanks or duplicates or the power programme shall be adjusted in accordance with the number of samples

NOTE If a temperature controlled microwave unit is used the appropriate temperatures of 110 to 120°C should be obtained for about 5 minutes. These are the temperatures that should be reached with the power programme of table 1, otherwise the power should be adjusted to reach these temperatures.

At the end of the programme let the vessels cool down to room temperature. Confirm that no losses of digestion solution occurred during the procedure (e.g. by control of burstmembran referring to the manufactures specifications or controll of mass). Otherwise the samples have to be discarded. Carefully uncap and vent each vessel in a fume hood, then transfer quantitatively the content of the vessels into a suitable sized volumetric flask and fill to the mark.

NOTE: If the digested sample contains particles which might clog the nebulizers of the measurement apparatus or which might interfere with the injection of the sample into the instrument, the sample solution may be centrifuged, allowed to settle or be filtered. In the case of filtration, dilute the content of the vessel before filtering, rinse and then fill to the mark of the volumetric flask. The method used has to be reported in the test report.

## 11 Test report

The work carried out by the testing laboratory shall be covered by a report which accurately, clearly and unambiguously presents the test results and all other relevant informations. The test report shall be issued separately or in conjunction with the report from the subsequent analytical method.

The test report shall include at least the following information:

- a) a reference to this European Standard ;
- b) complete identification of the sample ;
- c) information about the pre-treatment and extraction of the sample ;
- d) any detail not specified in this European Standard, or which are optional;
- e) any other information pertinent to the quality of the analytical data.

The test report may include the following information:

information about the sampling and sample pretreatment;

results of the analytical determinations carried out with other methods on the same samples, if any.

The traceability of the work carried out by the testing laboratory (e.g. instruments, worksheets, printouts, forms with samples weight) shall be recorded and stored. This information shall be available on customers request

NOTE: The final report should include all results and relevant information on the sampling, the digestion method and the analysis methods used.

Where the test is not carried out in accordance with this standard, reference may only be made to EN xxxx:2003 in the report in case all deviations from the procedures prescribed in this standard are indicated in the report stating the reasons for deviation.

## 12 Performance characteristics

Performance data in terms of repeatability and reproducibility will be available after validation by a round robin test.

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## Annex A (normative)

### Calibration of the power adjustment of the microwave oven

In order to compare the power adjustment of different apparatus among themselves, the actually supplied (effective) power must be determined. Also the relationship between the supplied power and the adjustment scale should be controlled. Furthermore the effective power should be checked periodically.

Calibration is carried out by heating a known amount of water during a fixed time period (e.g. 2 min) at different microwave power rates. Each raise of temperature has to be measured accurately to  $\pm 0,1$  °C after each heating cycle. The absorbed power is calculated from the raise of temperature (formula see at the end of annex A).

Put e.g. 1 kg of water in a plastic beaker (or a beaker made of other material that does not absorb or reflect microwave energy, glass beaker must be avoided), stir and measure the temperature. Place the beaker in the microwave oven. Do always select the same position. Set the microwave during 2 min at full power. Remove the beaker, stir and measure the final temperature. Repeat this procedure also at lower power rates.

The power absorbed is calculated with the following formula:

$$P = \frac{C_p \cdot m \cdot \Delta T}{t}$$

where:

$P$  is the power absorbed by the water in W (J/s)

$C_p$  is the specific heat for water J/kg °C (= 4184 J/kg °C)

$m$  is the mass of the water that is used for the calibration in kg

$\Delta T$  is the difference between initial and final temperature in °C

$t$  is the time period in s

If in the described procedure 2 min and 1 kg water are used, the formula can be simplified to:

$$P = \Delta T \cdot 34,87$$

## **Annex B** **(informative)**

### **Validation of methods – Data of EN 13657**

For information purposes validation data of EN 13657 for sewage sludge are listed below, additional data for soil and biowaste will be added when available.

During 1998-1999 a project for validation of this standard has been organised and carried out. The validation included an inter-laboratory study for evaluation of performance characteristics of methods included in the standard (reproducibility, repeatability, accuracy where applicable), and a robustness study (i. e. the evaluation of the influence of some defined operational parameters on the methods).

#### **C.1 Inter-laboratory study**

##### **C.1.1 Selection of laboratories**

A questionnaire has been circulated by all CEN/TC292/WG3 members to collect a list of interested European laboratories. About seventy laboratories gave their availability to participate to the inter-laboratory trial. All of them were asked to declare that they fulfill the minimum requirements to carry out digestion and analyses according to this standard. According to ISO 5725 series no selection has been made in advance on the basis of the supposed "ability" of laboratories, their certifications, etc: it's therefore possible to assume that participating laboratories are a rather good "sample" of "normal" European laboratories.

##### **C.1.2 Selection of samples**

- Sewage sludge was one of the selected materials of this validation trial:(CEN9/99 "SEWAGE SLUDGE SL11 POWDER");

For the evaluation of performances of digestion procedures, independently from the subsequent analyses performed on digested samples, all laboratories have been asked to analyse some already-prepared aqueous solutions with different degrees of difficulty (clean synthetic solutions, acid digested solutions). This has been used as a tool for discarding from the evaluation laboratories that didn't prove their analytical ability for some matrices/elements.

For accuracy evaluation, two certified reference material (CRM) have been also included:

- BCR 146R (sewage sludge);
- BCR 176 (city waste incineration ash).

All samples, including the two CRMs, have been delivered to laboratories in anonymous form.

##### **C.1.3 Experimental**

Preparation and homogenisation of samples, packaging, delivering, collection and evaluation of results have been carried out by Environmental Monitoring Sector of European Commission Joint Research Centre in Ispra (Italy).

##### **C.1.4 Results**

About fifty laboratories have actually returned results for the inter-laboratory study. The evaluation of results has been performed by following these steps:

- removing of "obviously erroneous data", both means and single data according to ISO 5725, part 2, 7.2.6;
- results from laboratories failing to correctly measure some elements in "clean metals" solution were removed from the whole data set (for the failed elements only);
- results from laboratories failing to correctly measure some elements in digested aqueous solutions were removed from the whole data set (for the failed elements only);
- the remaining data sets were evaluated according to ISO 5725 series, with calculation of repeatability, reproducibility and, where a "conventional true value" was available, accuracy (recovery); results of this evaluation are reported in the tables below.

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The inter-laboratory study involved a large number of laboratories, performing analyses in four replicates on several samples (five aqueous, six powders), for the determination of a large number of elements (up to 31), by using one to three digestion methods: this led to a very large data set. For some digestion methods and for some elements determination, only few data were available (a minimum of 24 outlier-free results is generally required); anyway, even for these methods and elements, useful information on performance have been obtained.

### **C.1.5 Conclusions**

The performances of the three methods have to be compared on an element-by-element, matrix-by-matrix basis, in the tables below. In general words, performances are actually well comparable, especially for most environmentally-sensitive elements.

Recovery rates for CRM: sewage sludge (BCR 146 R, non-refractory matrix) are in generally high, for CRM: city waste incineration ash (BCR 176, refractory matrix) in many cases low. Digestion with aqua regia will not necessarily release elements completely.



**SAMPLE CEN9/99 "SEWAGE SLUDGE SL11 POWDER"**

|    | Method A: Microwave assisted with aqua regia in closed vessel |    |    |            |            |         |          |          | Method - B: Microwave assisted, with aqua regia in semi-open vessel |   |    |            |            | Method C: Thermal heating, with aqua regia in reflux systems |          |          |    |    |    |            |            |         |          |          |
|----|---|----|----|------------|------------|---------|----------|----------|---|---|----|------------|------------|--|----------|----------|----|----|----|------------|------------|---------|----------|----------|
|    | N   | L  | NA | XREF mg/kg | Mean mg/kg | Recov % | Reprod % | Repeat % | N   | L | NA | XREF mg/kg | Mean mg/kg | Recov %  | Reprod % | Repeat % | N  | L  | NA | XREF mg/kg | Mean mg/kg | Recov % | Reprod % | Repeat % |
| Al | 67  | 16 | 5  |            | 81848      |         | 6.7      | 2.5      | 21  | 6 | 1  |            | 77368      |  | 16.7     | 1.7      | 29 | 7  | 0  |            | 79678      |         | 24.6     | 6.4      |
| Sb | 16  | 4  | 0  |            | 1949       |         | 103.9    | 25.6     | 5   | 2 | 1  |            | 2.57       |  | 29.7     | 0.5      | 3  | 1  | 1  |            | 2.2        |         | -        | 8.6      |
| As | 19  | 5  | 4  |            | 4.43       |         | 78.1     | 22.2     | 4   | 1 | 0  |            | 5.55       |  | -        | 10.1     | 17 | 5  | 0  |            | 4.03       |         | 58.5     | 16.2     |
| B  | 33  | 8  | 2  |            | 279.9      |         | 15.6     | 3.4      | 12  | 3 | 1  |            | 282.6      |  | 14.1     | 0.9      | 19 | 4  | 0  |            | 328.1      |         | 28.4     | 16.6     |
| Ba | 51  | 12 | 8  |            | 76.52      |         | 8.6      | 2.7      | 22  | 6 | 4  |            | 75.52      |  | 4.5      | 1.2      | 27 | 6  | 0  |            | 61.8       |         | 18.9     | 7.9      |
| Be | 13  | 3  | 0  |            | 1.79       |         | 147.8    | 29.3     | 0   | 0 | 0  |            |            |  |          |          | 5  | 1  | 0  |            | 1.45       |         | -        | 17.6     |
| Cd | 30  | 7  | 20 |            | 0.23       |         | 32.1     | 16       | 14  | 3 | 0  |            | 0.9        |  | 153.6    | 29.5     | 14 | 3  | 4  |            | 0.74       |         | 142.8    | 73.8     |
| Ca | 60  | 14 | 0  |            | 57232      |         | 11       | 5.9      | 19  | 5 | 5  |            | 58797      |  | 4        | 5.8      | 21 | 5  | 0  |            | 58521      |         | 17.2     | 2.6      |
| Cr | 92  | 23 | 10 |            | 77.24      |         | 10.2     | 4        | 31  | 8 | 0  |            | 73.0       |  | 10.2     | 2.9      | 40 | 9  | 4  |            | 78.47      |         | 19.6     | 5.8      |
| Co | 39  | 11 | 4  |            | 4.59       |         | 24.9     | 8.6      | 12  | 4 | 0  |            | 5.43       |  | 48.1     | 52.5     | 26 | 6  | 0  |            | 3.16       |         | 53.5     | 12.4     |
| Cu | 96  | 23 | 5  |            | 96534      |         | 13.2     | 3.5      | 31  | 8 | 0  |            | 93526      |  | 6.3      | 1.4      | 31 | 7  | 13 |            | 91351      |         | 3.3      | 2.6      |
| Fe | 81  | 20 | 7  |            | 4440.3     |         | 11       | 3.6      | 26  | 7 | 0  |            | 4437.7     |  | 4.2      | 2.3      | 43 | 10 | 4  |            | 4021.1     |         | 10.6     | 7.2      |
| Pb | 96  | 23 | 7  |            | 9327.5     |         | 11.2     | 2.9      | 31  | 8 | 0  |            | 9323.8     |  | 3.5      | 1.2      | 33 | 8  | 14 |            | 9305.6     |         | 5.6      | 3.6      |
| Mg | 60  | 14 | 0  |            | 2309.1     |         | 14.2     | 4.2      | 21  | 6 | 4  |            | 2177.3     |  | 5        | 2.9      | 21 | 5  | 0  |            | 1992.1     |         | 19       | 5.6      |
| Mn | 92  | 23 | 5  |            | 590.2      |         | 12.2     | 3        | 31  | 8 | 0  |            | 583.8      |  | 3.6      | 1.4      | 46 | 11 | 5  |            | 587.6      |         | 9        | 2.8      |
| Hg | 27  | 7  | 12 |            | 0.14       |         | 52.7     | 10.8     | 10  | 2 | 0  |            | 0.33       |  | 21.8     | 8.4      | 15 | 3  | 4  |            | 0.19       |         | 46.7     | 9.7      |
| Mo | 22  | 6  | 1  |            | 4.33       |         | 11.1     | 6.4      | 14  | 3 | 0  |            | 4.59       |  | 62.2     | 11.9     | 13 | 3  | 0  |            | 3.56       |         | 6.8      | 7.4      |
| Ni | 100   | 25 | 5  |            | 1729.6     |         | 10.6     | 3.3      | 26  | 7 | 5  |            | 1720.0     |  | 5.5      | 1.7      | 40 | 9  | 9  |            | 1568.6     |         | 18.7     | 6.1      |
| P  | 18  | 4  | 10 |            | 4724.5     |         | 3.8      | 6.3      | 22  | 5 | 0  |            | 5834.6     |  | 33.9     | 5.6      | 13 | 3  | 0  |            | 4012.9     |         | 24.7     | 6.7      |
| K  | 48  | 12 | 4  |            | 629.5      |         | 39.1     | 6.8      | 11  | 3 | 0  |            | 436.3      |  | 31.7     | 5.5      | 21 | 5  | 0  |            | 467.8      |         | 58.6     | 3.8      |
| Se | 8   | 2  | 0  |            | 7.03       |         | 110.2    | 14       | 0   | 0 | 0  |            |            |  |          |          | 0  | 0  | 0  |            |            |         |          |          |
| Ag | 28  | 7  | 0  |            | 10.53      |         | 14.7     | 13.1     | 18  | 4 | 0  |            | 7.73       |  | 20.5     | 11.8     | 18 | 4  | 0  |            | 9.68       |         | 21       | 7        |
| S  | 26  | 6  | 0  |            | 61982      |         | 8.8      | 1.7      | 7   | 2 | 0  |            | 60496      |  | 2.6      | 2.5      | 10 | 2  | 0  |            | 59698      |         | 12.8     | 1.8      |
| Na | 64  | 15 | 0  |            | 11041      |         | 22.7     | 6        | 7   | 2 | 0  |            | 12596      |  | 7.7      | 1.3      | 28 | 6  | 1  |            | 11805      |         | 10.8     | 4.3      |
| Sr | 41  | 10 | 10 |            | 200.8      |         | 5.6      | 2.4      | 15  | 4 | 0  |            | 197.3      |  | 3.3      | 2.2      | 18 | 4  | 0  |            | 195.2      |         | 9.5      | 2.2      |
| Sn | 35  | 8  | 5  |            | 19155      |         | 5.2      | 6.6      | 15  | 4 | 0  |            | 16768      |  | 15.1     | 5.1      | 14 | 3  | 0  |            | 17840      |         | 18.2     | 1.8      |
| Te | 0   | 0  | 0  |            |            |         |          |          | 0   | 0 | 0  |            |            |  |          |          | 0  | 0  | 0  |            |            |         |          |          |
| Tl | 6   | 2  | 0  |            | 18.65      |         | 203      | 9.6      | 0   | 0 | 0  |            |            |  |          |          | 0  | 0  | 0  |            |            |         |          |          |
| Ti | 21  | 5  | 0  |            | 29.78      |         | 28.2     | 8.9      | 8   | 3 | 4  |            | 26.34      |  | 10.1     | 0.5      | 12 | 3  | 0  |            | 24.64      |         | 35.7     | 3        |
| V  | 25  | 7  | 14 |            | 6.36       |         | 17.6     | 2.3      | 15  | 4 | 0  |            | 8.09       |  | 63.9     | 28.8     | 18 | 4  | 5  |            | 6.83       |         | 77.1     | 32.3     |
| Zn | 99  | 24 | 4  |            | 228.1      |         | 34.9     | 5.5      | 31  | 8 | 0  |            | 323.3      |  | 44.6     | 7        | 48 | 11 | 5  |            | 209.6      |         | 35.5     | 23       |

N = Number of results, L = Number of laboratories, NA = Number of outliers, XREF = Conventional true value (where applicable)

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**SAMPLE GEN10/99 "SEWAGE SLUDGE" (BCR 146R)**

|           | <i>Method A: Microwave assisted with aqua regia in closed vessel</i> |    |    |            |            |         |          |          | <i>Method - B: Microwave assisted, with aqua regia in semi-open vessel</i> |    |    |            |            |         |          |          | <i>Metho</i> |    |
|-----------|--|----|----|------------|------------|---------|----------|----------|--|----|----|------------|------------|---------|----------|----------|--------------|----|
|           | N  | L  | NA | XREF mg/kg | Mean mg/kg | Recov % | Reprod % | Repeat % | N  | L  | NA | XREF mg/kg | Mean mg/kg | Recov % | Reprod % | Repeat % | N            | L  |
| <b>Al</b> | 79   | 20 | 0  | 25130      | 20652      | 82,2    | 19       | 6,1      | 20   | 6  | 1  | 25130      | 18943      | 75,4    | 13,7     | 2,1      | 37           | 9  |
| <b>Sb</b> | 29   | 7  | 2  | 16,25      | 9,33       | 57,4    | 21,5     | 7,6      | 13   | 4  | 0  | 16,25      | 11,28      | 69,4    | 31,9     | 5,2      | 19           | 5  |
| <b>As</b> | 29   | 8  | 4  | 6,3        | 5,52       | 87,6    | 31       | 11,6     | 13   | 3  | 0  | 6,3        | 8,39       | 133,3   | 34,9     | 12,5     | 29           | 7  |
| <b>B</b>  | 23   | 6  | 0  |            | 38,7       |         | 37,3     | 15       | 11   | 3  | 0  |            | 30,87      |         | 33,8     | 6        | 15           | 4  |
| <b>Ba</b> | 63   | 15 | 0  | 735        | 572,8      | 77,9    | 20       | 4,6      | 19   | 5  | 1  | 735        | 391,8      | 53,3    | 16,9     | 7,7      | 23           | 5  |
| <b>Be</b> | 22   | 5  | 4  |            | 0,75       |         | 5,7      | 6,1      | 4  | 1  | 0  |            | 1,09       |         | -        | 9,1      | 13           | 3  |
| <b>Cd</b> | 82   | 20 | 14 | 18,76      | 17,15      | 91,4    | 8,8      | 4,5      | 22   | 6  | 4  | 18,76      | 15,75      | 84      | 13       | 2,3      | 45           | 11 |
| <b>Ca</b> | 60   | 14 | 0  | 154600     | 140455     | 90,9    | 8,7      | 3,7      | 18   | 5  | 5  | 154600     | 145312     | 94      | 7,3      | 1,4      | 27           | 6  |
| <b>Cr</b> | 103  | 25 | 0  | 196        | 164,6      | 84      | 13,6     | 3,4      | 27   | 8  | 4  | 196        | 157,5      | 80,3    | 12,3     | 4,4      | 45           | 10 |
| <b>Co</b> | 64   | 17 | 0  | 7,39       | 6,08       | 82,3    | 19,2     | 5,7      | 22   | 7  | 0  | 7,39       | 7,59       | 102,8   | 37,4     | 22,5     | 31           | 8  |
| <b>Cu</b> | 112  | 27 | 0  | 837,9      | 806,7      | 96,3    | 13,3     | 7,3      | 35   | 10 | 5  | 837,9      | 798,9      | 95,3    | 9,4      | 2,3      | 30           | 7  |
| <b>Fe</b> | 89   | 22 | 0  | 16100      | 13889      | 86,3    | 11,7     | 3,6      | 21   | 6  | 5  | 16100      | 13922      | 86,5    | 6,8      | 1,9      | 34           | 8  |
| <b>Pb</b> | 98   | 24 | 0  | 608,7      | 530,8      | 87,2    | 13,3     | 3,4      | 31   | 8  | 0  | 608,7      | 562,9      | 92,5    | 7,6      | 1,7      | 42           | 10 |
| <b>Mg</b> | 64   | 15 | 0  | 10460      | 9031,3     | 86,3    | 9,3      | 3,3      | 21   | 6  | 5  | 10460      | 8449,2     | 80,8    | 8,1      | 1,9      | 30           | 7  |
| <b>Mn</b> | 92   | 23 | 0  | 323,5      | 274,4      | 84,8    | 10,9     | 2,8      | 37   | 9  | 0  | 323,5      | 281,4      | 87      | 8,6      | 1,6      | 43           | 10 |
| <b>Hg</b> | 41   | 10 | 0  | 8,62       | 7,39       | 85,7    | 25,1     | 10,8     | 18   | 5  | 0  | 8,62       | 8,73       | 101,3   | 16,8     | 6,9      | 31           | 7  |
| <b>Mo</b> | 32   | 8  | 4  |            | 7,95       |         | 8,1      | 5,2      | 15   | 4  | 0  |            | 8,51       |         | 21,3     | 5,7      | 16           | 4  |
| <b>Ni</b> | 105  | 26 | 0  | 69,7       | 62,54      | 89,7    | 21,7     | 4,6      | 31   | 8  | 0  | 69,7       | 59,17      | 84,9    | 15,3     | 2,7      | 49           | 11 |
| <b>P</b>  | 31   | 7  | 1  | 25600      | 27658      | 108     | 2,4      | 2,8      | 24   | 6  | 0  | 25600      | 30286      | 118,3   | 17,5     | 5        | 14           | 3  |
| <b>K</b>  | 56   | 14 | 0  | 5240       | 2025,6     | 38,7    | 34,7     | 17,3     | 16   | 5  | 1  | 5240       | 1306,2     | 24,9    | 24,8     | 9,4      | 30           | 7  |
| <b>Se</b> | 13   | 3  | 0  |            | 4,74       |         | 60       | 12,3     | 4  | 1  | 0  |            | 3,33       |         | -        | 7,9      | 2            | 1  |
| <b>Ag</b> | 38   | 9  | 0  |            | 190,9      |         | 23,1     | 1,9      | 24   | 6  | 0  |            | 205,9      |         | 6,6      | 5,2      | 18           | 4  |
| <b>S</b>  | 26   | 6  | 0  | 10620      | 9188,4     | 86,5    | 17,7     | 2,4      | 2  | 1  | 0  | 10620      | 9180,0     | 86,4    | -        | -        | 10           | 2  |
| <b>Na</b> | 44   | 11 | 6  | 1804       | 777,0      | 43,1    | 28,1     | 4,3      | 6  | 2  | 0  | 1804       | 481,8      | 26,7    | 5,9      | 10,1     | 41           | 9  |
| <b>Sr</b> | 46   | 11 | 5  | 1179       | 1027,2     | 87,1    | 4,9      | 2        | 11   | 3  | 1  | 1179       | 975,1      | 82,7    | 4,4      | 2,4      | 19           | 4  |
| <b>Sn</b> | 30   | 7  | 3  | 95,8       | 59,79      | 62,4    | 32,5     | 6,3      | 15   | 4  | 0  | 95,8       | 61,15      | 63,8    | 33       | 3,8      | 14           | 3  |
| <b>Te</b> | 0  | 0  | 0  |            |            |         |          |          | 0  | 0  | 0  |            |            |         |          |          | 0            | 0  |
| <b>Tl</b> | 4  | 1  | 0  |            | 4,12       |         | -        | 8,7      | 4  | 1  | 0  |            | 0,55       |         | -        | 11,9     | 4            | 1  |
| <b>Ti</b> | 30   | 7  | 0  | 2771       | 299,8      | 10,8    | 57,6     | 21,5     | 21   | 6  | 0  | 2771       | 182,8      | 6,6     | 59,4     | 19       | 14           | 3  |
| <b>V</b>  | 50   | 12 | 8  | 42,7       | 34,14      | 80      | 8,6      | 3,3      | 14   | 4  | 8  | 42,7       | 27,76      | 65      | 3,4      | 2,8      | 26           | 6  |
| <b>Zn</b> | 108  | 26 | 0  | 3061       | 2813,5     | 91,9    | 10,8     | 4,5      | 31   | 8  | 0  | 3061       | 2761,8     | 90,2    | 7,1      | 3,1      | 43           | 10 |

N = Number of results, L = Number of laboratories, NA = Number of outliers, XREF = Conventional true value (where applicable)

## SAMPLE CEN10/99 "SEWAGE SLUDGE" (BCR 146R)

|    | Method A: Microwave assisted with aqua regia in closed vessel |    |    |            |            |         |          |          | Method - B: Microwave assisted, with aqua regia in semi-open vessel |    |    |            |            |         | Method C: |          |    |    |    |
|----|---|----|----|------------|------------|---------|----------|----------|---|----|----|------------|------------|---------|-----------|----------|----|----|----|
|    | N   | L  | NA | XREF mg/kg | Mean mg/kg | Recov % | Reprod % | Repeat % | N   | L  | NA | XREF mg/kg | Mean mg/kg | Recov % | Reprod %  | Repeat % | N  | L  | NA |
| Al | 79  | 20 | 0  | 25130      | 20652      | 82.2    | 19       | 6.1      | 20  | 6  | 1  | 25130      | 18943      | 75.4    | 13.7      | 2.1      | 37 | 9  | 0  |
| Sb | 29  | 7  | 2  | 16,25      | 9,33       | 57.4    | 21.5     | 7.6      | 13  | 4  | 0  | 16,25      | 11,28      | 69.4    | 31,9      | 5,2      | 19 | 5  | 0  |
| As | 29  | 8  | 4  | 6,3        | 5,52       | 87.6    | 31       | 11,6     | 13  | 3  | 0  | 6,3        | 8,39       | 133,3   | 34,9      | 12,5     | 29 | 7  | 0  |
| B  | 23  | 6  | 0  |            | 38,7       |         | 37,3     | 15       | 11  | 3  | 0  |            | 30,87      |         | 33,8      | 6        | 15 | 4  | 0  |
| Ba | 63  | 15 | 0  | 735        | 572,8      | 77,9    | 20       | 4,6      | 19  | 5  | 1  | 735        | 391,8      | 53,3    | 16,9      | 7,7      | 23 | 5  | 0  |
| Be | 22  | 5  | 4  |            | 0,75       |         | 5,7      | 6,1      | 4   | 1  | 0  |            | 1,09       |         | -         | 9,1      | 13 | 3  | 0  |
| Cd | 82  | 20 | 14 | 18,76      | 17,15      | 91,4    | 8,8      | 4,5      | 22  | 6  | 4  | 18,76      | 15,75      | 84      | 13        | 2,3      | 45 | 11 | 0  |
| Ca | 60  | 14 | 0  | 154600     | 140455     | 90,9    | 8,7      | 3,7      | 18  | 5  | 5  | 154600     | 145312     | 94      | 7,3       | 1,4      | 27 | 6  | 1  |
| Cr | 103   | 25 | 0  | 196        | 164,6      | 84      | 13,6     | 3,4      | 27  | 8  | 4  | 196        | 157,5      | 80,3    | 12,3      | 4,4      | 45 | 10 | 4  |
| Co | 64  | 17 | 0  | 7,39       | 6,08       | 82,3    | 19,2     | 5,7      | 22  | 7  | 0  | 7,39       | 7,59       | 102,8   | 37,4      | 22,5     | 31 | 8  | 0  |
| Cu | 112   | 27 | 0  | 837,9      | 806,7      | 96,3    | 13,3     | 7,3      | 35  | 10 | 5  | 837,9      | 798,9      | 95,3    | 9,4       | 2,3      | 30 | 7  | 9  |
| Fe | 89  | 22 | 0  | 16100      | 13889      | 86,3    | 11,7     | 3,6      | 21  | 6  | 5  | 16100      | 13922      | 86,5    | 6,8       | 1,9      | 34 | 8  | 5  |
| Pb | 98  | 24 | 0  | 608,7      | 530,8      | 87,2    | 13,3     | 3,4      | 31  | 8  | 0  | 608,7      | 562,9      | 92,5    | 7,6       | 1,7      | 42 | 10 | 5  |
| Mg | 64  | 15 | 0  | 10460      | 9031,3     | 86,3    | 9,3      | 3,3      | 21  | 6  | 5  | 10460      | 8449,2     | 80,8    | 8,1       | 1,9      | 30 | 7  | 1  |
| Mn | 92  | 23 | 0  | 323,5      | 274,4      | 84,8    | 10,9     | 2,8      | 37  | 9  | 0  | 323,5      | 281,4      | 87      | 8,6       | 1,6      | 43 | 10 | 0  |
| Hg | 41  | 10 | 0  | 8,62       | 7,39       | 85,7    | 25,1     | 10,8     | 18  | 5  | 0  | 8,62       | 8,73       | 101,3   | 16,8      | 6,9      | 31 | 7  | 0  |
| Mo | 32  | 8  | 4  |            | 7,95       |         | 8,1      | 5,2      | 15  | 4  | 0  |            | 8,51       |         | 21,3      | 5,7      | 16 | 4  | 0  |
| Ni | 105   | 26 | 0  | 69,7       | 62,54      | 89,7    | 21,7     | 4,6      | 31  | 8  | 0  | 69,7       | 59,17      | 84,9    | 15,3      | 2,7      | 49 | 11 | 0  |
| P  | 31  | 7  | 1  | 25600      | 27658      | 108     | 2,4      | 2,8      | 24  | 6  | 0  | 25600      | 30286      | 118,3   | 17,5      | 5        | 14 | 3  | 0  |
| K  | 56  | 14 | 0  | 5240       | 2025,6     | 38,7    | 34,7     | 17,3     | 16  | 5  | 1  | 5240       | 1306,2     | 24,9    | 24,8      | 9,4      | 30 | 7  | 5  |
| Se | 13  | 3  | 0  |            | 4,74       |         | 60       | 12,3     | 4   | 1  | 0  |            | 3,33       |         | -         | 7,9      | 2  | 1  | 0  |
| Ag | 38  | 9  | 0  |            | 190,9      |         | 23,1     | 1,9      | 24  | 6  | 0  |            | 205,9      |         | 6,6       | 5,2      | 18 | 4  | 1  |
| S  | 26  | 6  | 0  | 10620      | 9188,4     | 86,5    | 17,7     | 2,4      | 2   | 1  | 0  | 10620      | 9180,0     | 86,4    | -         | -        | 10 | 2  | 0  |
| Na | 44  | 11 | 6  | 1804       | 777,0      | 43,1    | 28,1     | 4,3      | 6   | 2  | 0  | 1804       | 481,8      | 26,7    | 5,9       | 10,1     | 41 | 9  | 0  |
| Sr | 46  | 11 | 5  | 1179       | 1027,2     | 87,1    | 4,9      | 2        | 11  | 3  | 1  | 1179       | 975,1      | 82,7    | 4,4       | 2,4      | 19 | 4  | 0  |
| Sn | 30  | 7  | 3  | 95,8       | 59,79      | 62,4    | 32,5     | 6,3      | 15  | 4  | 0  | 95,8       | 61,15      | 63,8    | 33        | 3,8      | 14 | 3  | 0  |
| Te | 0   | 0  | 0  |            |            |         |          |          | 0   | 0  | 0  |            |            |         |           |          | 0  | 0  | 0  |
| Tl | 4   | 1  | 0  |            | 4,12       |         | -        | 8,7      | 4   | 1  | 0  |            | 0,55       |         | -         | 11,9     | 4  | 1  | 0  |
| Ti | 30  | 7  | 0  | 2771       | 299,8      | 10,8    | 57,6     | 21,5     | 21  | 6  | 0  | 2771       | 182,8      | 6,6     | 59,4      | 19       | 14 | 3  | 0  |
| V  | 50  | 12 | 8  | 42,7       | 34,14      | 80      | 8,6      | 3,3      | 14  | 4  | 8  | 42,7       | 27,76      | 65      | 3,4       | 2,8      | 26 | 6  | 0  |
| Zn | 108   | 26 | 0  | 3061       | 2813,5     | 91,9    | 10,8     | 4,5      | 31  | 8  | 0  | 3061       | 2761,8     | 90,2    | 7,1       | 3,1      | 43 | 10 | 6  |

N = Number of results, L = Number of laboratories, NA = Number of outliers, XREF = Conventional true value (where applicable)

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**SAMPLE CEN11/99 "CITY WASTE INCINERATION ASH" (BCR 17)**

|    | <i>Method A: Microwave assisted with aqua regia in closed vessel</i> |    |    |            |            |         |          |          | <i>Method - B: Microwave assisted, with aqua regia in semi-open vessel</i> |   |    |            |            |         |          |          | <i>Metho</i> |    |
|----|--|----|----|------------|------------|---------|----------|----------|--|---|----|------------|------------|---------|----------|----------|--------------|----|
|    | N  | L  | NA | XREF mg/kg | Mean mg/kg | Recov % | Reprod % | Repeat % | N  | L | NA | XREF mg/kg | Mean mg/kg | Recov % | Reprod % | Repeat % | N            | L  |
| Al | 65   | 16 | 4  | 101600     | 57116      | 56,2    | 15,7     | 5,2      | 21   | 6 | 5  | 101600     | 48606      | 47,8    | 6,9      | 3,2      | 29           | 7  |
| Sb | 42   | 10 | 5  | 412        | 262,5      | 63,7    | 13,9     | 7,5      | 19   | 5 | 0  | 412        | 277,0      | 67,2    | 1,6      | 3,2      | 18           | 4  |
| As | 67   | 17 | 1  | 93,3       | 85,2       | 91,3    | 28,2     | 5,9      | 10   | 3 | 0  | 93,3       | 88,57      | 94,9    | 4,6      | 2,9      | 36           | 8  |
| B  | 33   | 8  | 4  |            | 173,1      |         | 21,3     | 2,3      | 13   | 3 | 0  |            | 169,8      |         | 11,8     | 6,8      | 19           | 4  |
| Ba | 62   | 15 | 0  | 4500       | 1329,6     | 29,5    | 119,6    | 11,2     | 21   | 6 | 0  | 4500       | 1811,4     | 40,3    | 103,5    | 21,1     | 23           | 5  |
| Be | 30   | 9  | 1  |            | 1,89       |         | 15,9     | 10,4     | 4  | 1 | 0  |            | 1,75       |         | -        | 4,4      | 12           | 3  |
| Cd | 107  | 26 | 1  | 470        | 422,7      | 89,9    | 13,7     | 3,2      | 31   | 8 | 0  | 470        | 428,3      | 91,1    | 7,9      | 2,1      | 38           | 9  |
| Ca | 48   | 11 | 0  | 88016      | 83012      | 94,3    | 8,2      | 3        | 24   | 6 | 0  | 88016      | 83050      | 94,4    | 5,3      | 3        | 26           | 6  |
| Cr | 106  | 26 | 1  | 863        | 210,7      | 24,4    | 17,7     | 6,5      | 30   | 8 | 1  | 863        | 164,7      | 19,1    | 15       | 2,6      | 48           | 11 |
| Co | 72   | 18 | 8  | 30,9       | 26,62      | 86,1    | 21,6     | 5,1      | 22   | 6 | 0  | 30,9       | 27,24      | 88,2    | 19,7     | 7,7      | 39           | 9  |
| Cu | 115  | 28 | 1  | 1302       | 1154,1     | 88,6    | 11,1     | 3,1      | 30   | 8 | 1  | 1302       | 1143,5     | 87,8    | 6,3      | 4,1      | 38           | 9  |
| Fe | 92   | 23 | 0  | 21300      | 18866      | 88,6    | 10,5     | 3,2      | 26   | 7 | 0  | 21300      | 18598      | 87,3    | 4,3      | 2,2      | 38           | 9  |
| Pb | 101  | 25 | 3  | 10870      | 10146      | 93,3    | 8,7      | 2,5      | 31   | 8 | 0  | 10870      | 10206      | 93,9    | 8,7      | 2,7      | 48           | 11 |
| Mg | 56   | 13 | 4  | 21720      | 11731      | 54      | 10,7     | 6        | 26   | 7 | 5  | 21720      | 10851      | 50      | 5,8      | 2,4      | 27           | 6  |
| Mn | 94   | 24 | 0  | 1500       | 1269,3     | 84,6    | 8,4      | 2,3      | 22   | 6 | 4  | 1500       | 1245,1     | 83      | 2,1      | 2,1      | 43           | 10 |
| Hg | 52   | 13 | 0  | 31,4       | 29,86      | 95,1    | 24,9     | 7,7      | 22   | 6 | 0  | 31,4       | 25,57      | 81,4    | 31,6     | 4,3      | 29           | 7  |
| Mo | 42   | 10 | 4  |            | 43,58      |         | 13,5     | 5,8      | 17   | 5 | 5  |            | 49,6       |         | 15,9     | 2,4      | 17           | 4  |
| Ni | 100  | 25 | 0  | 123,5      | 91,42      | 74      | 14,6     | 4,9      | 31   | 8 | 0  | 123,5      | 78,43      | 63,5    | 16,5     | 4,2      | 38           | 9  |
| P  | 32   | 7  | 0  |            | 6212,5     |         | 5,3      | 2,3      | 24   | 6 | 0  |            | 6114,7     |         | 14,8     | 3,3      | 27           | 6  |
| K  | 58   | 14 | 0  | 44986      | 31613      | 70,3    | 16,7     | 5        | 13   | 4 | 0  | 44986      | 35334      | 78,5    | 20,5     | 1,5      | 15           | 3  |
| Se | 30   | 7  | 0  | 41,2       | 41,66      | 101,1   | 14,5     | 5,4      | 6  | 2 | 0  | 41,2       | 36,92      | 89,6    | 7,3      | 8,5      | 13           | 3  |
| Ag | 37   | 9  | 0  | 60         | 55,75      | 92,9    | 23,3     | 5,2      | 22   | 5 | 0  | 60         | 69,13      | 115,2   | 19,3     | 3,5      | 24           | 5  |
| S  | 26   | 6  | 0  | 44600      | 29051      | 65,1    | 14,2     | 5,2      | 0  | 0 | 0  | 44600      |            |         |          |          | 10           | 2  |
| Na | 64   | 15 | 0  | 42920      | 26037      | 60,7    | 19       | 2,6      | 7  | 2 | 0  | 42920      | 32251      | 75,1    | 11,2     | 0,2      | 27           | 6  |
| Sr | 50   | 12 | 1  | 433        | 335,2      | 77,4    | 14,1     | 2,4      | 13   | 4 | 2  | 433        | 335,1      | 77,4    | 10       | 2,5      | 18           | 4  |
| Sn | 38   | 9  | 5  |            | 2500,4     |         | 5,1      | 2,8      | 11   | 3 | 4  |            | 2418,7     |         | 0,8      | 0,5      | 13           | 3  |
| Te | 0  | 0  | 0  |            |            |         |          |          | 5  | 1 | 0  |            | 24,2       |         | -        | 5,4      | 0            | 0  |
| Tl | 7  | 3  | 0  |            | 5,74       |         | 69,8     | 6,5      | 4  | 1 | 0  |            | 1,44       |         | -        | 9,1      | 4            | 1  |
| Ti | 26   | 6  | 1  | 8520       | 3538,2     | 41,5    | 21,8     | 3,1      | 19   | 5 | 0  | 8520       | 2604,4     | 30,6    | 11,1     | 1,7      | 13           | 3  |
| V  | 47   | 12 | 7  | 41         | 37,44      | 91,3    | 11,3     | 2,2      | 13   | 4 | 9  | 41         | 34,79      | 84,9    | 8,3      | 1,6      | 21           | 5  |
| Zn | 109  | 26 | 3  | 25770      | 23851      | 92,6    | 9,8      | 2,9      | 24   | 6 | 0  | 25770      | 23202      | 90      | 6,8      | 1,9      | 34           | 8  |

N = Number of results, L = Number of laboratories, NA = Number of outliers, XREF = Conventional true value (where applicable)

**Annex C**  
(informative)

**The modular horizontal system**

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**Annex D**  
(informative)

**Information on WP xx and the project Horizontal**

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