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How to judge release of dangerous substances from construction products to soil and groundwater

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Abstract
To be accepted on the EU market, construction products need to fulfil essential requirement number 3 as specified in the Construction Products Directive (89/106/EEC). This requirement states, among other, that the construction work must be designed and built in such a way that it will not be a threat to the quality of soil and groundwater by 'dangerous substances'. This work is meant as preparation and guidance to the work of CEN (European Comittee For standardization) and provides a generic approach to deal with the release of a broad range of contaminants from a wide range of construction products to soil and groundwater. The key question is if there is a potential 'unacceptable' release of contaminants from the construction product to soil & groundwater, and how this can be determined and judged. To answer the question three topics are worked out and reported separately:
Topic 1 - soil and groundwater impact. Based on identified release mechanisms and based on common ideas on how construction products can exhibit release to soil, surface and groundwater, a number of (partially fundamentally) different scenarios have been developed, for which more or less 'standard' model set-ups are developed or have to be developed. Each of the various construction products or product groups has been related to the (one or more) release scenarios that are representative for the material in its intended use.

For the allocation of test methods to each of the relevant product (groups), a limited number of existing EU standardized test methods of the characterization and compliance level have been taken into account. A 'hierarchy' in testing (topic 2) proves very practical in this context. A simplified step-wise impact assessment procedure (largely following on the ENV 12920, a step-wise methodology for the assessments of environmental impact) is proposed, which can establish a direct relationship between the results of a leaching test performed on a certain product to be used in a construction application and the quality of downstream groundwater influenced by leachate from the product.

In **Topic 2 -Hierarchy in testing**, some basic considerations concerning the conformity assessment of construction products in view of CPD/ER No. 3 are given. This results in a hierarchy of testing from Characterization and Initial Type Testing. In particular the proper characterization methods for Characterisation or Initial Type Testing of leaching behaviour of construction products to assess the release to soil and groundwater are identified. Such initial characterization should provide a basis of reference for a construction product or product group. Once the leaching character has been established, the construction product can be identified to demonstrate that the material being judged meets the specifications either as WT-product (Without Testing - no testing required) or as WFT-product (Without Further Testing) or as FT-product (Further Testing) respectively.

In **Topic 3** a proposal is done for reference to ER 3 aspects in product standards and in CE marking. First, a brief description is given on a number of important regulatory and standardization aspects. Next, an example is given on how reference to ER3 aspects can be made in product standards and in CE marking.

Contents

List of tables

List of figures

1. CPD Topic 1 - Soil and groundwater impact

1.1 Summary

For construction products to be accepted on the EU market they need to fulfil essential requirement number 3 as specified in the Construction Products Directive (89/106/EEC). This work is meant as preparation and guidance to the CEN work on dangerous substances and provides a generic approach to deal with the release of a broad range of contaminants from a wide range of construction products to soil and groundwater. The key question is if there is a potential 'unacceptable' release of contaminants from the construction product to soil & groundwater and how this can be determined.

Based on identified release mechanisms and based on common ideas on how construction products can exhibit release to soil, surface and groundwater, a number of (partially fundamentally) different scenarios have been developed, for which more or less 'standard' model set-ups are developed or have to be developed.

Each of the various construction products or product groups has been related to the (one or more) release scenarios that are representative for the material in its intended use.

For the allocation of test methods to each of the relevant product (groups), a limited number of existing EU standardized test methods of the characterization and compliance level have been taken into account. A hierarchy in testing proves very practical in this context.

A simplified step-wise impact assessment procedure (largely following on the ENV 12920, a step-wise methodology for the assessments of environmental impact) is proposed, which can establish a direct relationship between the results of a leaching test performed on a certain product to be used in a construction application and the quality of downstream groundwater influenced by leachate from the product.

1.2 Introduction

In the beginning of 2005 the European Commission, DG Enterprise, will mandate the European Standardization Organisation CEN to prepare test methods with which construction products in the EU can be tested with respect to the potential release of dangerous substances to soil and groundwater and to indoor air. This action is intended to satisfy the needs resulting from Essential requirement number 3 as specified in the Construction Products Directive (89/106/EEC). These test methods will be coupled to regulatory limits that a broad range of construction products has to fulfil to be accepted on the EU market (Construction Products Directive, CPD). An expert working group under the European Commission, DG Enterprise, and Construction Unit has supported the drafting of the mandate. CEN is also involved already, as the Environmental Project of the Construction Sector Network (CSNPE) has taken the initiative to set up a horizontal Technical Committee (CEN/TC).

This report is the result of a joint project of the Energy Research Centre of the Netherlands (ECN, NL) and the Verein Deutscher Zementwerke (VDZ, D), commissioned by order of the Federal Environmental Agency (UBA, D) in cooperation with the German Standardisation Organisation (DIN, D) and the Netherlands Standardization Institute (NEN, NL). This work is meant as preparation and guidance to the CEN work on dangerous substances and provides a generic approach to deal with the release of a broad range of contaminants from a wide range of construction products to soil and groundwater. The key question is if there is a potential 'unacceptable' release of contaminants from the construction product to soil & groundwater, and how this can be determined. This question will be dealt with by addressing the following topics:

- Construction products are used in different configurations and exposure conditions, called 'application scenarios'. However, recent investigations have shown that only a limited set of chemical/physical factors is responsible for the release for a wide range of (primary and secondary) construction products, and in practice, only a few of those factors dominate. Based on this experience, we expect that a limited set of fundamentally different scenarios covers a wide range of possible applications of a broad group of construction products (e.g., directly exposed to rain, directly in contact with soil, etctera). How many relevant and different scenarios can be identified?
- For each product or product group, which of these scenarios will be relevant for practice (more than 1 scenario for a given product is possible)?
- How should widely different construction products be tested on their release potential? Are different tests needed for each different construction product or application scenario?
- How is the relation established between the test results and the regulatory criteria to be developed? Useful criteria can only be derived when they are based on the basis of an (expected) soil and/or groundwater quality on a certain distance of the construction product in its application ('point of compliance', which might be chosen anywhere). This relationship between the test result and soil/groundwater quality can only be established by setting up model scenarios for each of the (limited set of) application scenarios. Is such a relationship possible and what is the input needed for such models?

Each of the above listed topics will be treated and motivated separately in the following paragraphs 2-5. Due to the extensive lists of materials, mechanisms, scenarios and tests, the *results* are gathered in a spreadsheet that is an electronic appendix to this report. It contains tables with:

1. Descriptions and conceptual sketches of the different release scenarios identified (sheets named scen 1-7);
2. The allocation of the different construction products and material classes to one or more application scenarios (sheet named Products and scenarios;
3. The allocation of (EU standardized) test methods to each of the construction products and product groups (sheet Products and tests);
4. Brief descriptions of the dominant transport/chemical mechanisms of the release and transport in soil/groundwater, and input parameters needed for modelling (in the sheets scen 1-7).

The final paragraph (5) of this report contains an example of modelling a road base (scenario 1 of the results), which is composed of a top-layer of MSWI bottom ash, being a secondary construction product, placed on soil.

1.3 Development of different release scenarios relevant for construction products

Recent work (*1*) has shown that there is only a limited set of physical and chemical factors that control the release of substances from all sorts of materials such as construction products. These key parameters have been shown to be measurable with a limited set of testing methods. In addition, these key parameters form the basis of (to a higher or lesser extent) mechanistic models, in order to model release and further transport of contaminants in soil and groundwater to a certain point of compliance (POC) (*1*). Based on these mechanisms and based on common ideas on how construction products can exhibit release to soil, surface and groundwater, a number of (partially fundamentally) different scenarios have been developed, for which more or less 'standard' model set-ups are developed or have to be developed.

We found 7 different relevant scenarios; and of course, this implies that a lot of flexibility is included with respect to e.g., flow velocities, underlying soil characteristics, location of the point of compliance etcetera. However, the input parameters retrieved from the tests per scenario are similar, and the modelling approach is also similar. The differences between these scenarios are largely based on the material and environmental characteristics, summarized below (see also (*1*):

- Is the product granular, monolithic or can it be regarded as a (metal) plate? This is of importance for the dominant transport mechanisms from the product (percolation, diffusion or runoff).
- Is the dominant release process some form of solubility control, or is it limited by diffusion? (This is in close connection with the previous characteristics, see (*1*)).
- Is wetting/drying of importance (exposed to rain), or is the product continuously in contact with water (exposed to surface water) or soil (direct contact with soil)?

The different scenarios are summarized in Table 1.1 below, and worked out in detail in the appendix. Similar scenarios have been described by DIBt (7).

Table 1.1 *Short description of the seven different release scenarios. The scenarios are explained in more detail in the appendix (Excel workbook)*

no.	Scenario description
1	Granular products placed on soil
2	Monolithic products placed on soil
3	Runoff (wet/dry) from monolithic product
4	Unbound granular materials e.g. construction debris (varying particle size; end-of-life)[1]
5	Pipes (e.g. drinking water pipes)[2]
6	Monolithic products in water (e.g., coastal works)
7	Runoff from metal plates

1 End-of-life stage is not under the scope of the CPD, but may be important in judging acceptability of materials for use.

2 Release to both the transported water as well as the surrounding soil.

From a modelling point of view, there may even be a considerable overlap between the scenarios sketched above or an application may be constituted of a combination of two or more release scenarios, in which the resultant impact may need to be determined.. For instance, the 'end-of-life' stage (scenario 4), currently not under the scope of the CPD, may consist of a size-reduced-version of the original product, for which the scenario will be similar to scenario 1. Similarly, a model description of scenario 6 (monolithic products directly in contact with water) is needed to set up the models for scenario 5 (pipes) and 3 (wet/dry cycle of monolith products), which are obviously more complex.

A judgement related to 'end of life' may become relevant, when a construction product has no environmental impact issues during service life, but potential impact problems arise in the recycling or 'end of life' stage of the product life cycle. In such case, it may be wise from a precautionary principle to deal with the recycling or 'end of life' issue before admission. Since the tools described here allow such judgement beforehand, there is no need for additional development of methods to tackle this problem.

As a guidance for future developments, we have assigned *priorities* in relevance to each scenario for each product or product group (see appendix). For instance, for aggregates bound in concrete (for road construction), the direct interaction with soil is probably more important than runoff itself. These priorities, which are assigned based on experience, can be used as a guidance as to which model scenarios have to be developed first for the specific product groups.

Below, we have made an overview of the key parameters for which a decision has to be made on their magnitude (Table 1.2). For instance, for the development of a scenario model, a choice has to be made on parameters such as the annual precipitation rate (mm/yr), the height of the application and the location of the point(s) of compliance (POC). More detailed information on the set-up of the model scenarios and the needed parameters can be found in the appendix.

Table 1.2 *Overview of key parameters on which a decision has to be made on their magnitude in order to further define model scenarios*

no.	Scenario description	Key parameters
1	Granular products placed on soil	height, infiltration rate, soil characteristics, POC
2	Monolithic products placed on soil	soil characteristics, POC
3	Runoff (wet/dry) from monolithic product	runoff and wet/dry regime, soil characteristics, POC
4	Construction debris (varying particle size; end-of-life)	wet/dry regime, soil characteristics, POC
5	Pipes (e.g. drinking water pipes)	wet/dry regime, water characteristics (hard soft drinking water), POC
6	Monolithic products in water (e.g., coastal works)	water characteristics (surface water, seawater, dw?), POC
7	Runoff from metal plates	water characteristics (rainwater), POC

In Table 1.2, 'soil characteristics' and 'water characteristics' are of course lump parameters. These are composed of several factors such as (for 'soil characteristics'): organic matter content of a standard soil, clay content, content of iron(hydr)oxide surfaces, hydraulic conductivity, etcetera.

Besides choices on scenario parameters as sketched above, some choices have to be made of 'typical ' release characteristics for each product, in order to define the appropriate 'source term'. These characteristics should be based on measurement data. A database/expert system can play an important role for this aspect. For the different characterization tests, key parameters that need to be defined are:

- *Percolation test:* L/S concentration relationships for different elements (specific for product (groups)).
- *Tank test:* Effective diffusion coefficients for different elements, quantity of wash-off effects (specific for product (groups)).
- *pH-dependence test:* investigation of solubility controlling processes in a unified manner. Such a procedure will be available in LeachXS (6).

1.4 The allocation of the different construction products and product groups to one or more application scenarios

Each of the construction products or product groups has to be related to the (one or more) release scenarios that are representative for the use of the material in its actual application. It was not considered efficient to address scenario evaluation on a material-by-material basis, as this might lead to criteria setting by material type, which from a regulatory perspective is highly inefficient and undesirable. The allocation of release scenarios to each product is based on the characteristics listed in the previous paragraph (monolithic/granular, solubility control expected, etcetera). For the analysis, a list of the different products and groups has been compiled by NEN and is listed in Table 1.3 below.

Table 1.3 *Products and product groups used in construction*

Aggregates	Metal injection anchors for use in concrete for fixing lightweight systems
Aggregate in concrete (bound)	Non-load bearing permanent shuttering kits
Aggregate in road base (unbound)	Pipes, tanks and ancillaries not in contact with water
Aggregate as structural fill (unbound)	Plastic anchors for use in concrete and masonry
Cements, Building limes and other hydraulic binders	Post-tensioning kits for pre-stressing of structure
Concrete, mortar, Grout and related products	Prefabricated stair kits
Construction adhesives	Reinforcing and pre-stressing steel for concrete
Curtain walling	Road construction products
Doors, windows, shutters, gates etc.	Asphaltic products
External thermal insulation	Roof coverings, roof lights, roof windows an ancillary products
Fire stopping, fire sealing and fire protection products	Sanitary appliances
Fixed fire fighting systems	Self-supporting translucent roof kits
Floorings	Space heating appliances
Geotextiles	Structural bearings
Glass products	Structural metallic products
Gypsum products	Structural timber products (preserved)
Internal & external wall and ceiling finishes	Systems of mechanically fastened flexible roof water proofing membranes
Internal partition kits	Thermal insulating products
Light composite wood based beams and columns	Timber frame and log fabricated building kits
Liquid applied waterproofing kits	Waste water engineering products (concrete?)
Masonry and related products	Woodbased panels
Membranes	Drinking water pipes (concrete)
Metal anchors for concrete	

Almost all materials listed in Table 1.3 can somehow be related to one or more of the release scenarios of Table 1.1. For instance, a certain type of brick should be allocated to one of the 'monolithic' scenarios (2, 3 or 6 in Table 1.1). In this example, the brick can be used either above the ground, exposed to rain (in that case, 'runoff' and wet/drying cycles are important, scenario 3) and/or directly in contact with soil (scenario 2).

However, for some products of Table 1.3, it is expected that the release is very low compared to the overall release from a final application (e.g., a building, a construction works). This implies that for some material classes, release of dangerous substances to soil and groundwater is not relevant, or currently thought to be not relevant, and do not need further analysis (and testing, see next paragraph) beforehand. To make a first systematic analysis of the categories *relevant in regard to release into soil, groundwater and surface water* (shown in the overview in the appendix), we have looked at the following aspects:

- Not the construction materials (e.g. cement, sand, lime, filler) used to make a construction product are tested as such in regard to their release behaviour; the constituents are tested as a part of the final product or the final product is tested as a whole. Examples of materials that are not to be tested as such in this respect are cement, limes and hydraulic binders, which are regarded as 'not relevant' because only the final product (e.g. concrete) is relevant in release scenarios. Of course 'ingredients' have a certain influence on the release of the final product, but this influence is hard to quantify without detailed (geo)chemical knowledge. The influence of these ingredients on the release is generally not 'additive', i.e. the final release is not necessarily the sum of the individual contributions (possible exception to this principle are salts). These considerations are the reason why only the release behaviour of the final product should be tested. In practise it is in many cases nevertheless necessary to integrate release tests into the product standards of also intermediate products in case product standards for a final product do not exist. Also, for some materials certain tests on the content or elution of pollutants may be mandatory (e.g. chromate concentration in cement). These tests are not covered in the scope of this report.

- Materials such as the steel/plastic armors in concrete are expected to contribute negligible to the overall leaching of the product and are therefore considered to be not relevant.
- Products used purely indoors, do not get in contact with rain and soil/groundwater, and are therefore not relevant (only probably in the end-of-life stage). Products with a very low surface area or volume may also fall in the category 'not relevant'.
- Products that do not contain dangerous substances do not form a hazard to soil and groundwater (e.g. window panes).

When a product (group) is considered not to have a relevant release potential, it is also *not relevant for testing* in the context of impact to soil and groundwater. A more detailed description on criteria on which materials might be placed on a 'positive list' or 'WFT' (without further testing) is referred to in topic 2 of these projects.

In the appendix, in the worksheet 'products and scenarios', is listed which materials are considered to be relevant or not relevant in the sense that they might show a certain release of dangerous substances to soil and groundwater. For the materials in the class 'relevant', one or more typical release/exposure scenarios are indicated. The number of potentially dangerous substances relevant from a regulatory perspective is larger than the number of substances relevant for a given construction product. This aspect will be addressed in topic 2 of these projects.

1.5 The allocation of test methods to each of the different products or product groups

A testing 'hierarchy' as developed in CEN TC 292 (waste) has proven its applicability for a wide variety of alternative and waste materials, and is also suitable for construction products (*1*). Three basic levels are distinguished in the testing hierarchy:

1. *Characterization tests*; used for basic characterization (or initial testing) of the release of the product. All the relevant parameters for an impact assessment are measured. These data allows for the assessment of products by categories, based on common controlling mechanisms, and therefore reduce the amount of products within a product group that require characterization. This type of data is necessary for scenario modelling, but can be also for insight in variability of measurements, expected range under field conditions, quality improvement (relevant for producers), once the dominant mechanisms are clear.
2. *Compliance tests*, which have the purpose to 'check' with a simple test whether a material (still) complies with the previous characterization and subsequently with criteria. Once the leaching behavior has been investigated by characterization, a simple test measuring the same property (e.g., leaching at a certain pH) suffices. A close relationship between characterization and compliance should be ensured.
3. *On-site verification / quality control tests* are quick tests to see whether a material complies with earlier determined or expected behavior, in its practical application. In general, a simple chemical measurement (e.g. pH, redoc, conductivity), an administrative or visual check may be done in this case. For a real confident chemical check, at least a compliance test should be done.

The main advantage that such a testing hierarchy has, is that once a characterization step has been done, much more simplified testing on compliance level can be chosen to verify the consistency of subsequent data with the characterization test results. This is very time- and cost efficient. For examples and a detailed description of (characterization level) test methods and how they can be used for several purposes is referred to van der Sloot and Dijkstra (*1*). For the allocation of test methods to each of the relevant product (groups), we have taken into account a limited number of existing EU standardized test methods of the characterization and compliance level. These are summarized in Table 1.4.

Table 1.4 *Characterization and compliance test methods*

Test #	Brief description	Level
prEN14429	pH-dependence test, on granular or size-reduced products	characterization
prEN14405	column test, on granular products	characterization
EN12457-2	batch test (natural pH), granular products	compliance
EN12457-3	serial batch test, granular products	compliance
wi292040	dynamic monolith leaching test (DMLT, tank test)	characterization
wi292010	compliance tests, monoliths	compliance
EN1250	Tank test for preserved wood (monoliths)	compliance

Of course the characterization level test methods provides those parameters that are needed for an impact assessment, which is made by modelling the scenarios that are sketched in paragraph 2. In the next paragraph we will briefly introduce the modelling approach and give an example on how test results are to be related to criteria, or how criteria can be derived from the test results (*vice versa*). In the appendix (worksheet 'Products and tests') we have assigned the suitable test methods for each relevant product or product group. The limited set of tests listed in Table 1.4 is large enough to cover a whole range of products and application scenarios, as has been shown in more detail by van der Sloot and Dijkstra (*1*) (see appendix).

Organic micro pollutants

Some products (e.g. asphalt products, construction debris) may require more characterization tests than the ones listed here. In asphalt products, construction debris and others, the release of organic micro pollutants may be important. To measure the leaching of PAH, PCB and other organic micro pollutants, additional or different leaching protocols have to be developed that deal with specific laboratory aspects (e.g., sorption to vials) and analytical aspects. However, like other (inorganic) contaminants, their release is also governed by the same release mechanisms although the chemical interactions may differ. Still release is a function of parameters such as pH, L/S and time (in case of monolithic material), therefore these tests should be based on similar principles. In view of perceived complexity, in several jurisdictions these parameters are addressed by regulating their total composition.

The relation between total composition and leaching in judging impact will be addressed in more detail in topic 2 of this project.

1.6 Relating test results to criteria set in soil and groundwater (point of compliance)

1.6.1 Step wise impact assessment procedure (applied to groundwater quality)

Hjelmar (*2*) presents a simplified step-wise impact assessment procedure (largely following on the ENV 12920, a step-wise methodology for the assessments of environmental impact), which can establish a direct relationship between the results of a leaching test performed on a certain product to be used in a construction application, and the quality of downstream groundwater influenced by leachate from the product. It is evident that many elements of this procedure apply to different types of scenarios as well, albeit with some minor modifications.

The method may be used in a '*forward mode*' for site-specific environmental impact assessments, but it may also be used in a '*backwards mode*' to develop leaching limit values, which are associated with a certain level of protection of the downstream groundwater. This idea is schematically sketched below (in this case for a road construction product, scenario 1).

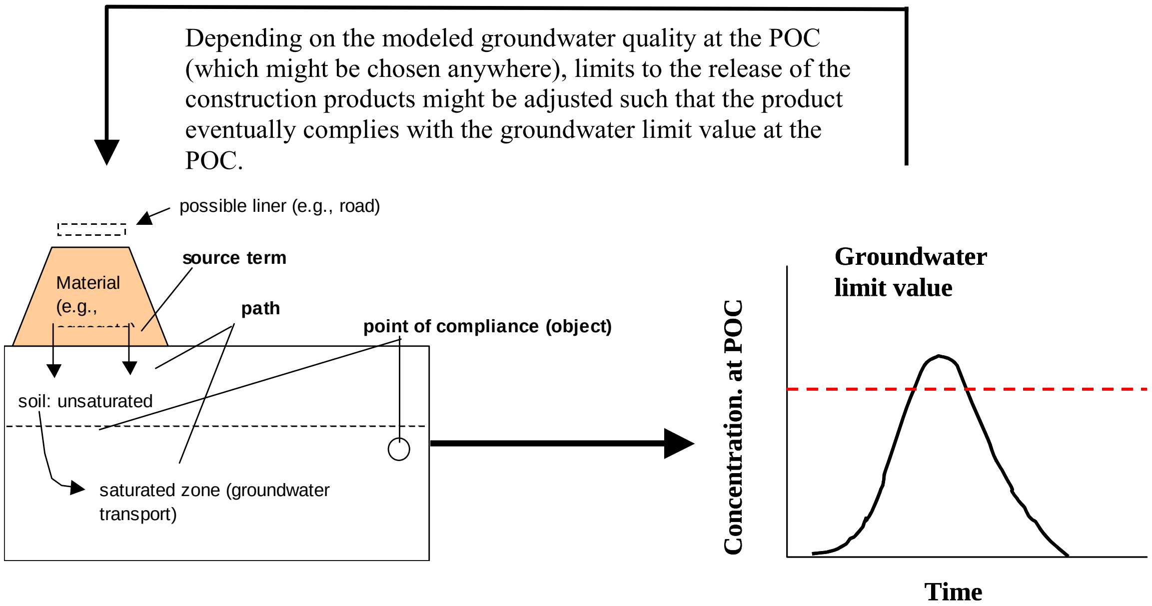


Figure 1.1 *Illustration of the 'backward mode' for the step-wise impact procedure. Test results are related to a certain impact (concentration at a chosen point of compliance, POC) by modelling. The result of the exercise can be used in return to set limits to the release of the product (mg/kg or mg/m^2) such that the quality objective will not be exceeded.*

This methodology has been used by the TAC (Technical Adaptation Committee with representatives from EU Member states) to develop the European leaching limit values for acceptance of waste at various types of landfills in accordance with the EU Landfill Directive (1999/31/EC and 2003/33/EC). The method allows some flexibility in terms of choice of test methods, but it is very important that the mechanisms controlling the release of contaminants from the materials in question are identified correctly and that the test methods prescribed or used are consistent with this information. The following is a brief outline of the procedure followed (source: (2)).

In this context, the procedure is used to set limit values for a material to be used in a construction project. Only the impact on groundwater quality is considered. First a decision must be made concerning the primary target(s) or point(s) of compliance (POC), e.g. the downstream point(s) where the groundwater quality criteria must be fulfilled. Quality criteria are then selected for the groundwater and the physical characteristics of the construction project scenario and the environment scenario are selected and described. In the example of impact on groundwater shown before, concentrations measured at a 'point of compliance' (e.g., a drinking water well) further downstream the application, are subject to dilution and attenuation in the subsoil. The latter factors determine the peak concentration in the groundwater.

The environment scenario includes the net rate of infiltration and a hydrogeological description of the unsaturated and saturated (aquifer) zones upstream, below and downstream of the construction application. The source of the various contaminants is subsequently described in terms of the flux of contaminants as a function of time based on leaching data and the hydraulic scenario defined. Then the migration of the contaminants through the unsaturated zone into the groundwater and through the aquifer to the POC(s) is described with particular reference to the (depending on the modelling capabilities) distribution coefficient (Kd-values) for each contaminant, which are used to calculate the retardation factors.

The next step is to select and fit one or more models that can be used to describe the water flow and transport of contaminants from the base of the landfill through the unsaturated and saturated zones to the POC(s). The model calculations are carried out and 'attenuation factors' (for granular materials the ratio between the source peak concentration and the peak concentration as modeled at the groundwater POC) are determined for each contaminant and POC.

Next, the attenuation factors are then used for a 'backwards' calculation of the values of the source term corresponding to the selected groundwater quality criteria for each contaminant at a particular POC. The final step consists of transforming the resulting source term criteria to a limit value for a specific leaching test. The step-wise procedure is summarized below:
1. Choice of primary target(s) and principles
2. Choice of critical parameters and primary criteria values
3. Description of the material application scenario
4. Description of the environment scenario
5. Description of the source of potential contamination
6. Description and modelling of the migration of the contaminants from the application to the POC(s)
7. Performance of 'forward' modelling to determine attenuation factors
8. Application of the results to criteria setting ('backwards' calculation)
9. Transformation of the source term criteria to limit values at different L/S values

It should be noted that the procedure involves numerous simplifications and generalizations of complex and diverse physical-chemical processes. Only inorganic contaminants from largely inorganic materials are, for instance, considered. This is justified by the need to have an operational and relatively simple system, which can be used for the development of general criteria. Many of the technical details involved in this procedure are discussed in more detail in e.g., Hjelmar (*2*).

1.6.2 Hierarchy in modelling approaches: simple and advanced mechanistic

The relationship between the test result and the limit values for release is through scenario modelling (e.g., previous paragraph). Generally, there are two ways to model the leaching from a product and/or the fate of the contaminants in the environment: a mechanistically based model approach or an empirical model approach. It is preferred to use the latter approach when possible, and a more advanced approach when needed. The more advanced modelling is in some cases preferred over an empirical approach, e.g. when a product shows changes over time that may be relevant for leaching (e.g., the lowering of the pH of concrete due to reaction with carbon dioxide). For other applications, it is often more convenient to be able to quantify the leaching process in terms of simple mathematical formulas. Both model approaches require input from the test results.

With respect to the mechanistic modelling approach, much progress has been made in recent years to predict the leaching of contaminants from complex and heterogeneous primary and secondary construction products (e.g., (*3*)). Also, significant improvement has been made recently to predict the fate of contaminants such as heavy metals in soils using a similar approach (e.g., (*4*)). These models, however, require a thorough characterization of leaching characteristics and parameters in the laboratory (characterization level tests such as a pH-dependence test) and advanced geochemical modelling and modelling skills. For more detail on these modelling approaches is referred to the cited literature.

For practical purposes, often-simple empirical models are used to assess the leaching of contaminants from waste materials, such as a first-order decay function (see below). The leaching of inorganic contaminants may be described as an initial peak concentration of the contaminant in the leachate, followed by an exponential decrease of the concentration with time (or L/S). If it is assumed that a continuously stirred tank reactor (CSTR) model can be used to interpret the

results of a column-leaching test on *granular* materials, the leaching of several components may be expressed by a simple decay function:
$C = C_0 * e^{-(L/S)\,k}$

Where:

C is the concentration of the contaminant in the leachate as a function of L/S (mg/l).
C_0 is the initial peak concentration of the contaminant in the leachate (mg/l).
L/S is the liquid to solid ratio corresponding to the concentration C (l/kg).
k 'kappa', is a first-order constant describing the rate of decrease of the concentration as a function of L/S for a given material and a given component (kg/l).

For *monolithic* materials, the Tank test (NEN 7345, similar to the w129040 test in development in CEN) foresees in a relatively simple and still semi-mechanistic description of the release by diffusion. The fitted effective diffusion coefficient (D_e) can be used to make predictions beyond the time scale of the test and in special situations such as wetting/drying cycles.

For transport in soil and groundwater, the simplest approach is that of a distribution coefficient ('Kd'). The approach of a first-order decay function to describe the leaching of contaminants from landfilled waste materials, together with a Kd-approach to describe the further transport in soil and groundwater, was followed recently to derive limit values for landfilling (Annex II, EU Landfill Directive).

1.6.3 Example of modelling scenario 1: road construction materials

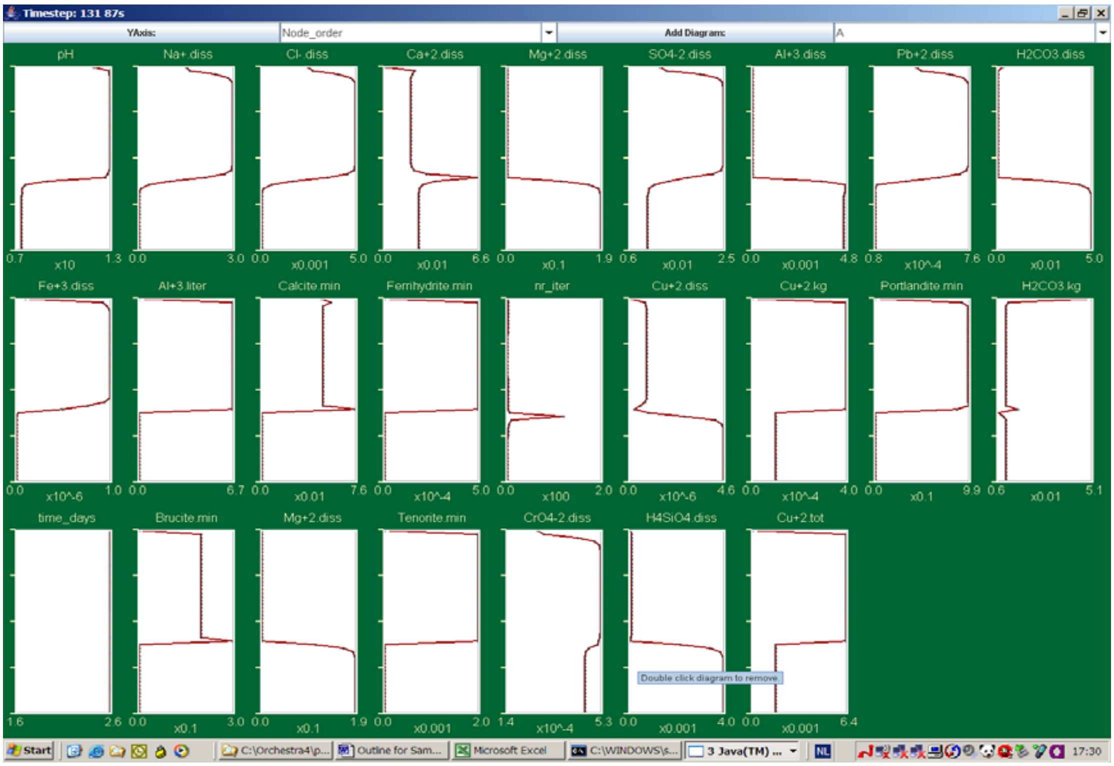
An example of the possibilities for modelling is shown in the figures below for a road base (scenario 1), composed of MSWI bottom ash (top layer, 0.3 m) placed on soil (0.2 m). The modelling framework ORCHESTRA (Objects Representing CHEmical Speciation and TRAnsport models, (*5*)) is used to identify the release controlling processes in the different starting materials (the bottom ash and the soil under study) and to set up the scenario model. The scenario used for illustration here is relatively simple though detailed in mechanistic aspects: 1-dimensional transport, net infiltration 0.3 m/year (average precipitation in the Netherlands). Chemical characteristics from the bottom ash and the soil were taken from characterization tests on samples analyzed in the laboratory. These data were taken from the database/expert system LeachXS (*6*). We will not elaborate here on the geochemical details of the modelling exercise.

The modelling comprised the following steps:

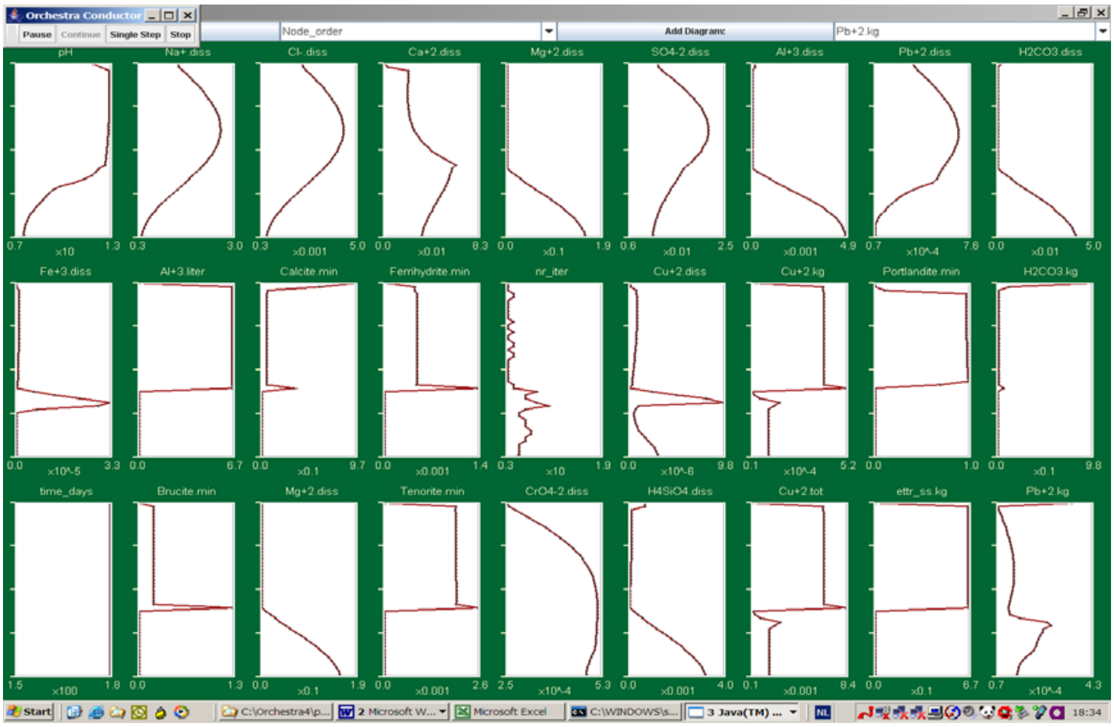
1. Measurement of release from the materials using a pH-dependence test (prENN14429).
2. Speciation modelling using LeachXS a database-coupled version of the modelling environment ORCHESTRA to identify relevant mineral phases.
3. Refined prediction of leaching behavior in a pH dependence test based on the selected minerals obtained by using ORCHESTRA in step 2.
4. This resulting speciation is used as input for the chemical reaction/transport modelling to describe the release from a granular material and the subsequent infiltration of the leachate in soil (the scenario).

As output the model provides concentration profiles in pore water as a function of depth, for specified time intervals over the desired duration of the field scenario. This allows visualization of the concentration development in the pore water as a function of depth and, simultaneously it shows precipitation/dissolution reactions at the interface. Similarly concentrations in the solid phase can be chosen as output, when needed. Obviously, such detailed modelling should be verified in field scale testing. There are a few field studies (e.g. Road base Vondelingenweg, Rotterdam, Netherlands) where this may be possible, but this is beyond the scope of this project.

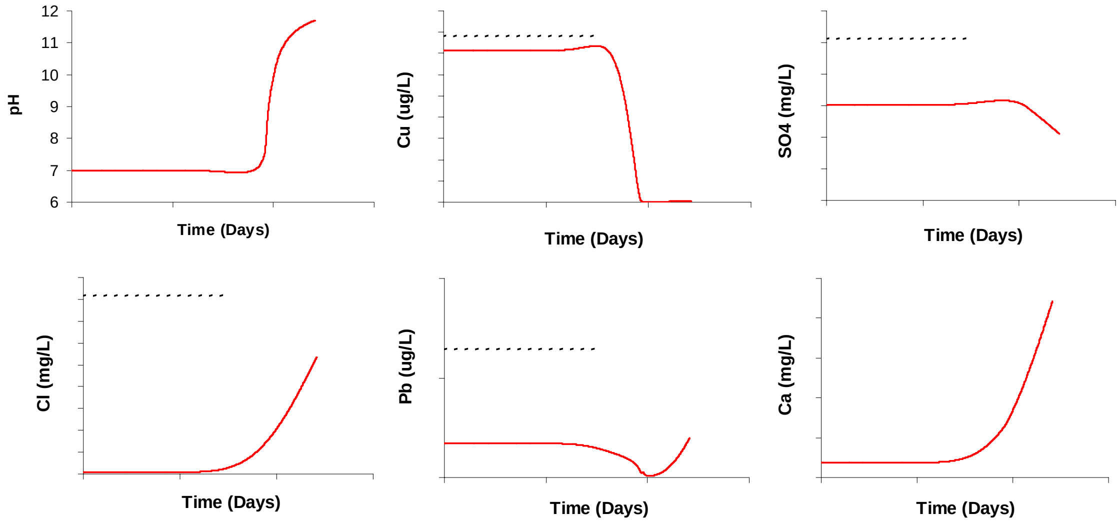
Point of compliance (POC)
There is debate on the points of compliance that have to be selected for the different possible scenarios. Using modelling for the translation of test results to impact, allows for the monitoring of concentrations at any distance from the source (the construction product) to an identified target (still to be determined). This stresses that in the stage of development of an impact assessment approach, the choice of the POC should not be the primary focus of the discussion.



Modelling a road construction scenario (scenario 1) for the start situation after 2,6 days (above) and 190 days (below) for a large number of substances in dissolved (.diss) or mineral (.min) form. On the vertical scale the depth (total 0.5 m), on the horizontal scale the concentration. The road base is made up by a layer of MSWI bottom ash (upper 0.3 m), which is placed on soil (lower 0.2 m). Modelled 1-D with a mechanistic modelling approach (full chemistry), 300 mm/yr. Note the complex concentration fronts of contaminants that develop at the interface.



The associated concentration as a function of time at a selected point of compliance (here 20 cm into the soil) is given below. This concentration can be judged against quality objectives see below).



Predicted concentrations as a function of time at given point of compliance compared with quality objectives (to be defined by regulators).

1.7 Conclusions

- A total of 7 different application scenarios relevant for release can be identified for the different construction products and product groups. The scenarios are identified based on different possible applications and factors that control the release, such as the product being a monolith (diffusion dominated release) or granular (percolation dominated release). Models have to be set up to describe these scenarios, with input from the test results.

- Each product from a list of 45 different construction products and product groups has been allocated to one or more relevant application scenarios. Some products or product groups are not relevant with respect to their release to soil and groundwater based on their function (e.g., used only indoors) or release potential.
- Of the products that are relevant for further study, i.e. that can have a potentially important release, suitable release test methods have been allocated at ‘characterization’ and ‘compliance’ level.
- With respect to the relation between test results and criteria setting, a concept has been outlined which used either simple or more advanced models to describe the release of substances from the product (source term) and their fate in soil and groundwater. This way, a ‘point of compliance’ can be chosen at any distance from the source. An impact evaluation strategy based on test results and subsequent modelling can be used in a ‘forward’ mode (for specific impact assessments) or in ‘backward’ mode, the latter to be used for development of limit values for the release of a certain construction product.

1.8 References

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2. CPD Topic 2 - Hierarchy in testing: Characterisation, initial type testing, further testing and selection of tests in specific stages of material judgement

2.1 Summary

In this part some basic considerations concerning the conformity assessment of construction products in view of CPD/ER No. 3 are given. This results in a hierarchy of testing from Characterization and Initial Type Testing. In particular the proper characterization methods for Characterisation or Initial Type Testing of leaching behaviour of construction products to assess the release to soil and groundwater are identified. Such initial characterization should provide a basis of reference for a construction product or product group. Once the leaching character has been established, the construction product can be identified to demonstrate that the material being judged meets the specifications either as WT-product (Without Testing - no testing required) or as WFT-product (Without Further Testing) or as FT-product (Further Testing) resp.

Based on the observed release in relation to regulatory criteria a description of a methodology to determine Without Testing (WT), Without Further Testing (WFT) and Further Testing (FT) from characterization testing or Initial Type Testing (ITT) is described. Examples of characterization versus compliance testing for conventional and alternative materials in construction are provided with quantitative information on the judgement.

2.2 Introduction

In the beginning of 2005 the European Commission, DG Enterprise, has issued a mandate to the European Standardization Organisation CEN to prepare test methods with which construction products in the EU can be tested with respect to the potential release of dangerous substances to soil and groundwater and to indoor air. This action is aimed to satisfy the needs resulting from Essential Requirement number 3 as specified in the Construction Products Directive [1]. These test methods will be coupled to regulatory limits that a broad range of construction products may have to fulfil according to the EU or Member State legislation in order to be accepted on the EU market (Construction Products Directive, CPD). An expert working group under the DG Enterprise Construction Unit has supported the drafting of the mandate. CEN is also involved already, as the Environmental Project of the Construction Sector Network (CSNPE) has taken the initiative to support the set up a horizontal Technical Committee (CEN/TC).

This report is the result of a joint project of the Energy Research Centre of the Netherlands (ECN, NL) and the Verein Deutscher Zementwerke (VDZ, D), commissioned by order of the Umweltbundesamt (UBA, D) in cooperation with the German Standardisation Organisation (DIN, D) and the Netherlands Standardization Institute (NEN, NL). This work is meant as preparation to the CEN work on dangerous substances and provides a generic approach to deal with the release of a broad range of contaminants from a wide range of construction products to soil and groundwater. The key question is if there is a potential 'unacceptable' release of contaminants from the construction product to soil & groundwater, and how this can be determined.

In this part the following topics are addressed:

- Establish a concept for the conformity assessment of construction products in view of CPD/ER No. 3.
- Identify the proper characterization methods for characterization or initial type testing of leaching behaviour of constituents to assess the release to soil and groundwater. Such initial characterization should provide a basis of reference for a material or material class.
- Once the leaching character has been established, the construction product can be identified to demonstrate that the material being judged meets the specifications either as WT-product [no testing required (Without Testing)] or as WFT-product (Without Further Testing) or as FT-product (Further Testing) respectively.
- Based on the observed release in relation to regulatory criteria a description of a methodology to determine Without Testing (WT), Without Further Testing (WFT) and Further Testing (FT) from characterization testing or Initial Type Testing (ITT) will be provided.
- Examples of characterization versus compliance testing for conventional and alternative materials in construction.

An illustration of relationships using actual data will be given in the Annexes for a granular and a monolithic construction material.

2.3 Conformity assessment of construction products in view of the cpd essential requirement No. 3

Figure 2.1 shows the procedures foreseen in the Mandate to assess the conformity of construction products in view of the CPD Essential Requirement No. 3. These procedures distinguish between WT-products and Non-WT-products, the latter including WFT-products and FT-products.

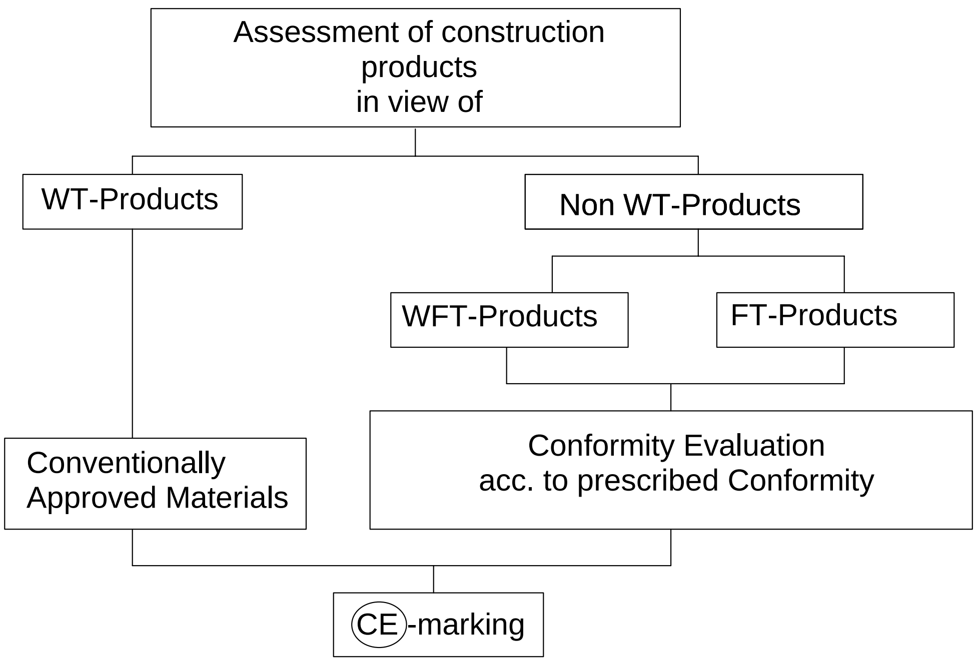


Figure 2.1 *Conformity assessment*

Figure 2.2 shows a conceptual scheme, how to identify products, which qualify to be accepted as Without Testing Products (WT-products).

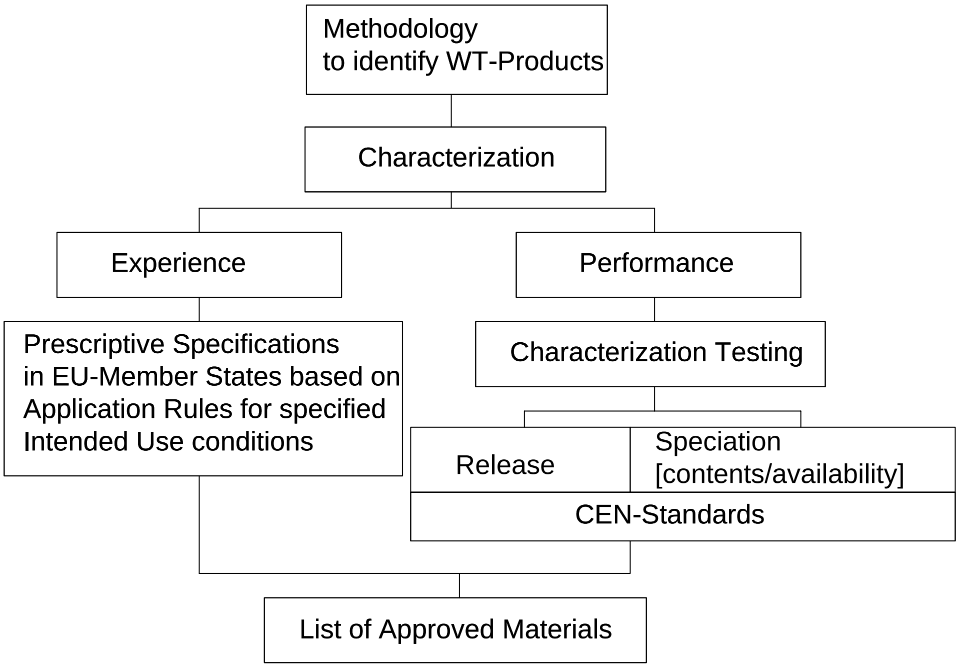


Figure 2.2 *Identification of WT - products*

Figure 2.3 shows the conformity evaluation of Non WT-products on the basis of their release performance.

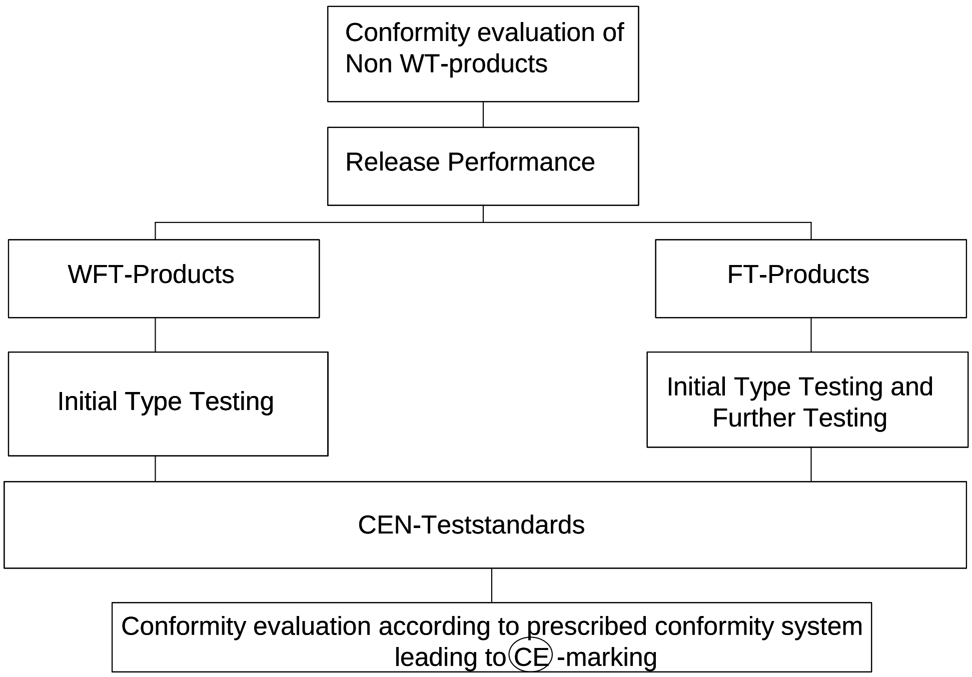


Figure 2.3 *Conformity evaluation of Non WT - products*

In Figure 2.4 the role of performance (release) based conformity assessment (Characterisation, Initial Type Testing and Further Testing) of construction materials to check compliance with regulatory requirements (see Part 1 of this work, in particular, the scenarios linking test data to practice), is shown schematically. Characterisation (see Figure 2.2) provides a basis of reference for a material or material class that is consistent within the material type or class, as materials produced to a certain specification have the tendency to show rather limited variability in properties (mechanical, physical and environmental). Once this character has been established, the decision can be taken if the construction product can be classified as ‘WT-product’ or if the evaluation of conformity requires Initial Type Testing (WFT-product) or even further testing (FT-product).

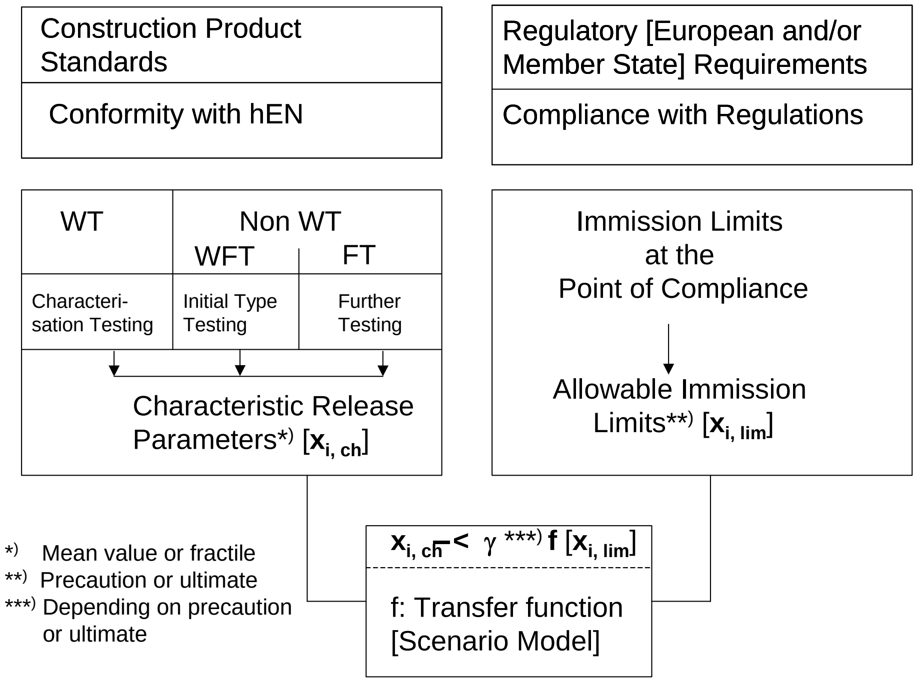


Figure 2.4 *The role of conformity assessment in view of compliance with regulations*

For easy reference to the characterization information such information should be readily assessable through a database capable of handling any type of test data and field data. In that manner, repeated characterisation of an already well characterised material in all EU member States and in particular in the recently joined EU member States will not be necessary. This aspect of data consistency is illustrated in Annex A and B for respectively cement mortars made according to EN 197 using world wide cements and municipal solid waste incinerator ash used in road construction as subbase.

Figure 2.5 summarizes the decision process for the conformity assessment.

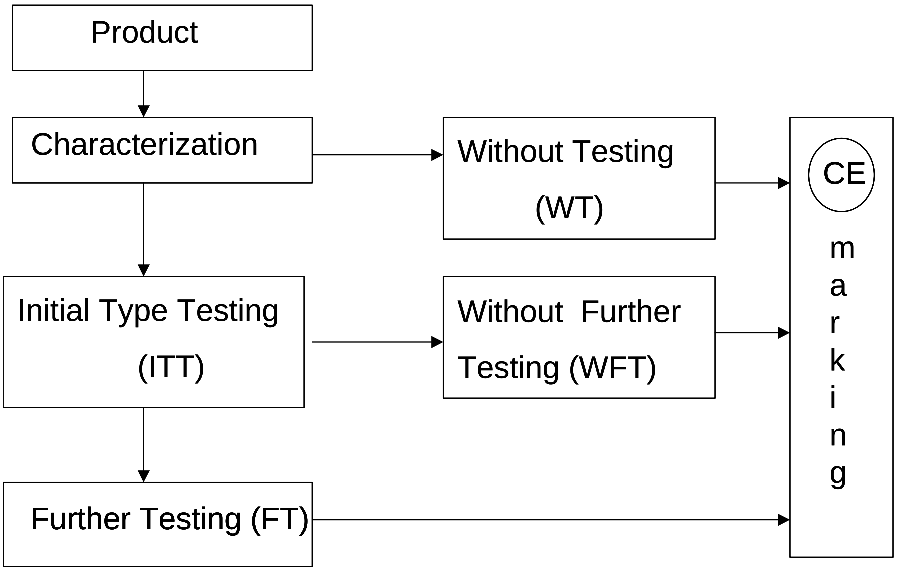


Figure 2.5 *Conformity assessment with CPD/ER3*

2.4 Characterization or initial type testing for release from construction products

Mechanisms and processes
To obtain a proper understanding of release of contaminants from granular as well as from monolithic construction materials, characterisation tests are crucial [2]. The distinction is necessary to be able to allow for the significantly different release mechanisms involved in both types of materials. This aspect must be reflected in the leaching tests.

Comment:
In CEN leaching test methods have been developed for a wide range of different waste materials. As any material may become a waste at some point in time, the scope of the leaching test methods developed for characterisation of waste is very broad. In recent years, these methods have been shown to be much more widely applicable.

The characterisation should focus on leaching mechanisms and controlling factors. The characterisation leaching data form the basis for the conformity assessment of construction products. They need to be correlated as closely as possible to actual processes and exposure conditions occurring in practice (see Part 1). The closer the leaching test data can be related to practice the more realistic the conformity assessment meets the practical conditions under intended use.

Comment:
Arbitrary tests will no doubt lead to conflicting situations, where the gap between perceived behaviour and actual behaviour in full scale application can be unacceptable large. Obviously, when the difference between lab and field is significant but well below any regulatory limit, there is no direct need for action. However, when the release gets closer to the regulatory limit, this aspect can become decisive in granting permission for use or rejection.

Characterization tests
The appropriate test for characterization of leaching behaviour of granular and monolithic materials are shown schematically in Figure 2.6. In some cases, content can provide useful information. The pH dependence-leaching test [3] is applicable to both granular and crushed monolithic materials. This test provides information on exposure conditions other than the own pH of the material. This is highly relevant for material deviating from a neutral pH condition, as that condition is by definition unstable due the driving force of the surroundings to equalise concentration gradients. The test also provides information on the chemical speciation and/or availability that can be used in mechanistic speciation models, which is very important for long-term prediction of leaching behaviour. The better the chemistry of a material is understood the better the prediction of long-term release behaviour and the better the options for quality improvement of products. In Annex C advantages and disadvantages are given for the characterisation methods proposed.

The percolation test [4] is the best method for a release process based on percolation of infiltration water through the *granular* matrix. The tank test [5] or similar [6] is the most relevant tool for assessing release from a *monolithic* material. For the materials excluded from the scope of a percolation test due to too low permeability, an alternative is available in the form of the compacted granular leach test [7], which also allows establishing release from a compacted granular material.

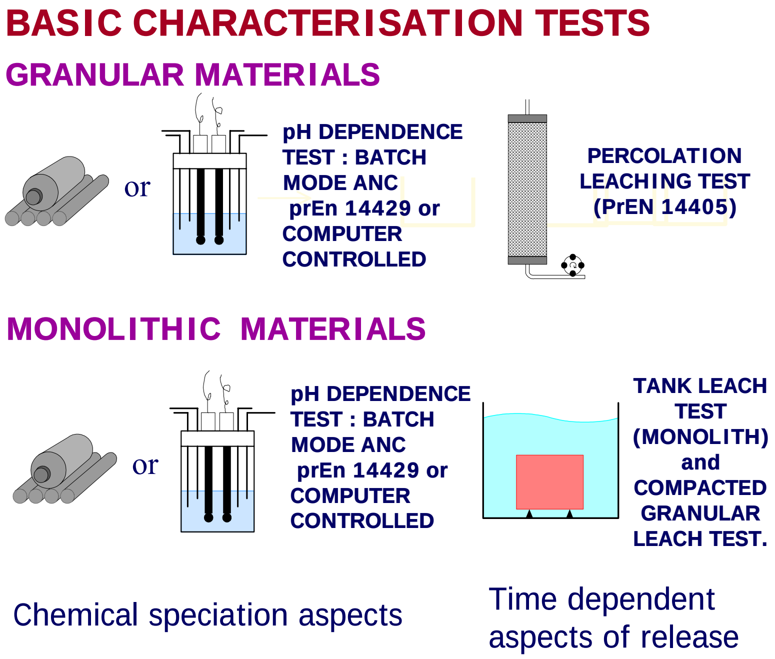


Figure 2.6 *Schematic representation of the characterization leaching tests for granular and monolith material suitable for a very wide range of different types of construction materials*

Examples

Examples of characterization data are given in Annex A and B for respectively cement mortars made according to EN 197 [8] using world wide cements and municipal solid waste incinerator ash used in road construction. Data are presented as a function of pH and as a function L/S (liquid to solid ratio in l/kg) and against time for dynamic leaching from monolithic materials.

For the cement mortars in Annex A the following information is shown:

- Leaching of crushed cement mortar in concentration (microgram/l) as a function of pH
- Leaching as measured concentration (microgram/l) as a function of time
- Leaching as cumulative release (mg/m^2) against time
- pH in the tank test as a function of time

The latter reflects testing under CO_2 exposed conditions for some of the specimen.
The expression of release in mg/m^2 as a function of time is the most relevant means of data presentation for monolithic materials.

For the municipal solid waste incinerator ash in Annex B the following information is shown:

- Leaching of MSWI Bottom ash in concentration (mg/kg) as a function of pH
- Leaching as measured concentration (microgram/l) as a function of L/S
- Leaching as cumulative release (mg/kg) against L/S
- pH in the column eluates as a function of L/S.

Data interpretation and use

Figure 2.7 shows the many different aspects that are covered by a combination of the pH dependence-leaching test and a percolation test as proposed (see also Annex C for test use). These aspects relate to other exposure conditions that the own pH, comparison with regulatory criteria, identification of the relevant pH domain for the application, indication of pore water quality, quality control testing in relation to characterisation, relationship between pH dependence test and column leaching test as corresponding L/S.

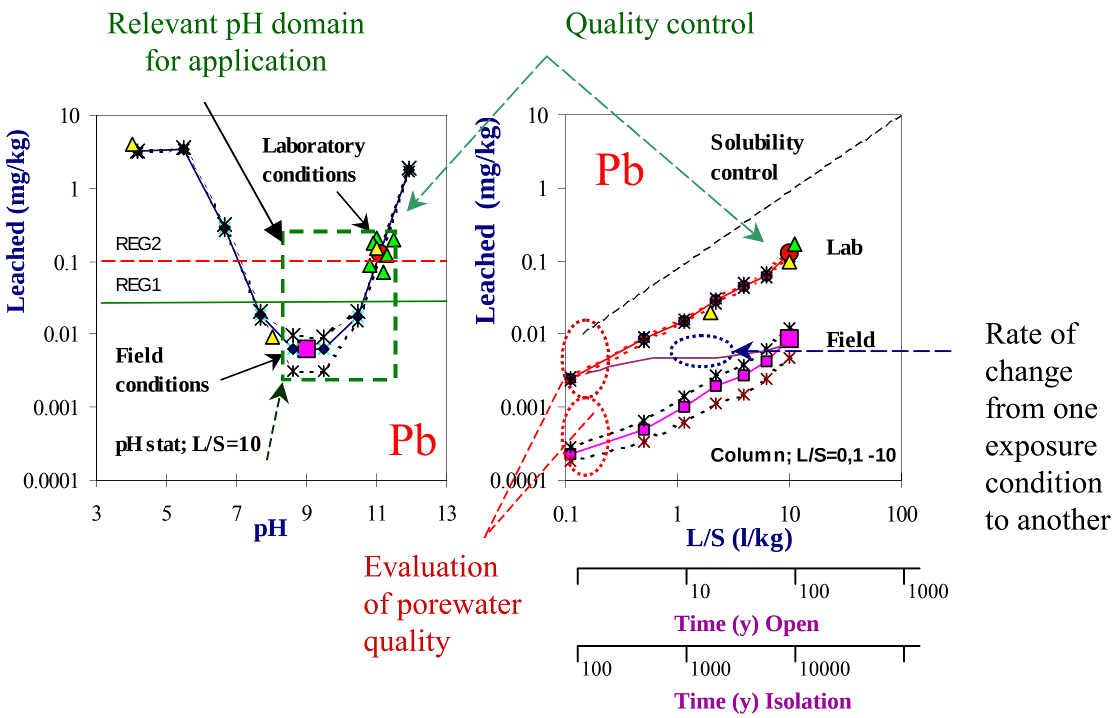


Figure 2.7 *Multiple conclusions that can be drawn from the characterization of granular materials using a combination of pH dependence leaching test and a percolation test for granular materials*

Once the leaching character has been established, strongly reduced testing will suffice to demonstrate that the material being judged meets the specifications (compliance testing). This reduction in testing can be at different levels:

- Limited or one step test instead of several fractions in the leaching test (see also Part 1).
- Reduction of the number of parameters to be analysed (generally a limited number of parameters are relevant in any one material or material type).
- Frequency of testing (bonus-malus principle – performing well may lead to reduction in frequency of testing).

2.5 Evaluation of a procedure to decide on parameters or a material meeting criteria to classify as WT (Without Testing), WFT (Without Further Testing) AND FT (Further Testing)

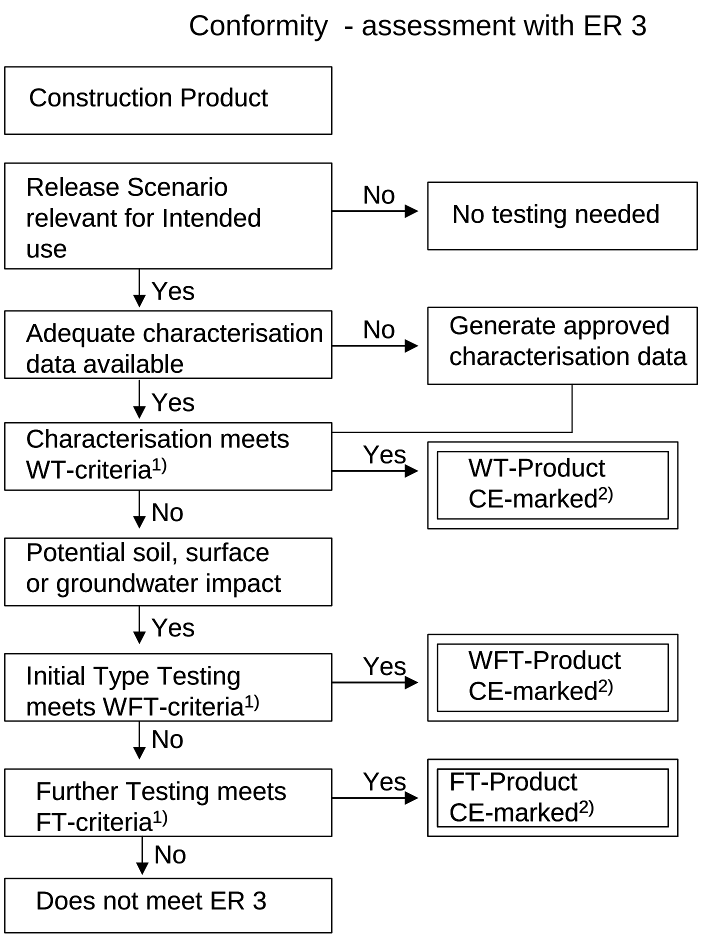
It is important objective to describe a consistent methodology to determine WT (Without Testing), WFT (Without Further Testing) and FT (Further Testing) from characterisation test results or ITT (Initial Type Testing) and to identify the relevant parameters for testing a material or material class and finally the frequency of testing based on uncertainty analysis and limit values.

WT, WFT and FT
Following the groundwork laid out in preceding chapters and in Part 1, in which the hierarchy of testing and the test use is described, the step can be made to address the methodology to derive criteria to decide on parameters or materials that can be classified as WT (Without Testing), WFT (Without Further Testing) and FT (Further Testing).

This can primarily be based on experience gained in long-term exposure under practical conditions and/or in well-documented and accepted laboratory performance.

Analytically the classification can be based on a comparison with a regulatory level, as that decides about compliance or not. This procedure is depicted schematically in Figure 2.8 below. Since criteria have not yet been established, we will use the Dutch Building Materials Decree values as reference for illustration purposes. For some WT materials the judgement will be based on properties, intended use and volume produced.

For analytical assessments a key issue is what factor [γ] below the regulatory limit value shall be used to state that a parameter meets WT-, WFT- or FT-criteria (see Figure 2.8). Only when all regulatory defined parameters meet these criteria it will be possible to decide that a material or product classifies in the corresponding category. To decide about a product group, the bandwidth of release parameters should meet the criteria for all individual parameters. A scheme showing subsequent decisions leading to applicability, or rejection is given in Figure 2.8.



1) WT, WFT and FT requirements to be developed horizontally and to be further detailed for the given construction products

2) Information to be supplied in the CE-mark for WT,WFT and FT products to be developed horizontally and to be further detailed for the given construction product

Figure 2.8 *Scheme showing subsequent decisions leading to conformity with ER 3 or rejection*

Protection level of regulatory limits

Regulatory limits are either defined as precautionary or as ultimate limits. Precaution means to choose immission limits in such a way as to assure that human and/or ecotoxicity under long-term ‘in-service’ exposure conditions remains below intensities, which are acceptable on the basis of experience and scientific knowledge. Ultimate limits mean that human and/or ecotoxicity reach intensities beyond which release is unacceptable on the basis of experience and scientific knowledge. The safety margin and corresponding factors (factor γ, see Figure 2.4) between allowable immissions and precautionary limits is by definition smaller than the safety margin against ultimate limits. Consequently it is important to clearly identify the protection level expressed by regulatory limits when assessing the release performance of construction materials in view of the conformity classes WT, WFT or FT.

Frequency
Characterization testing is generally carried out only once to classify a well-defined construction product as WT-product. The frequency for Initial Type Testing and Further Testing as elements of the conformity evaluation may differ from one construction product to another. In particular a bonus-malus principle can be applied for Further Testing. This means that when a producer performs well (i.e. within the limit values) this may lead to reduction in frequency of testing; until such time that an exceedence occurs. At that point the frequency is stepped up one step. When performance is good for a certain amount of time frequency can go down again.

Proposed factors
Agreement on the factors between the trigger criteria and the limit value needs to be established. First of all the nominal value of the safety factors depend on the level of protection anticipated by the regulatory limit. Furthermore the safety factors depend on the statistical information of the emission parameter to which they are applied. Precautionary limits set barriers against in service long-term conditions and should not be met by the mean or – if necessary – by a well-selected quartile of the emission, hence the safety factor is about 1 (which would be in accordance with an analogous field of structural safety). Ultimate limits set barriers to extreme emission parameters, which occur with lower probabilities. Consequently safety factors applied to mean emission parameter should be greater than 1 to protect against ultimate limits.

2.6 Materials without testing (WT)

In Annex 1 of Part 1 materials are listed, for which it is considered not necessary to test for their release in service life. There may be a need to test such materials in recycling and end-of-life conditions (outside scope of current CPD). In table I proposed materials Without Testing (WT) are listed with a brief explanation of the reason testing is not considered necessary.

Table 2.1 *Materials without testing (WT)*

		TESTING NEEDED	
	PRODUCTFAMILIES IN CONSTRUCTION	no	not sure
7	Construction adhesives		A
8	Curtain walling		?
11	Fire stopping, fire sealing and fire protection products		A
12	Fixed fire fighting systems		B
15	Glass products	C	
17	Internal & external wall and ceiling finishes		A
18	Internal partition kits		C
19	Light composite wood based beams and columns		A
22	Membranes		A
23	Metal anchors for concrete	C	
24	Metal injection anchors for use in concrete to fix lightweight systems	C	
25	Non-load bearing permanent shuttering kits	C	
26	Pipes, tanks and ancillaries not in contact with water	A	
27	Plastic anchors for use in concrete and masonry	C	
28	Post-tensioning kits for pre-stressing of structure	C	
29	Prefabricated stair kits	C	

30	Reinforcing and pre-stressing steel for concrete	C
34	Sanitary appliances	C
35	Self-supporting translucent roof kits	C
36	Space heating appliances	C
37	Structural bearings	C
41	Thermal insulating products	A

Explanation

A	Relevant for the release scenarion Indoor Air or End-of Life issue (incineration, disposal, …)
B	Potentially relevant for radioactivity, not relevant from soil & groundwater impact
C	Not relevant for soil & groundwater impact

For several materials listed in Table 1 the leachability is marginal (e.g. glass, membranes, specific plastics) justifying placement on a WT products list. For some materials considerations related to recycling or 'end of life' may be relevant for ultimate judgement.

2.7 Materials without further testing (WFT)

The approach as outlined in the scheme presented in Figure 2.5 forms the basis for evaluation of construction products with specified WFT parameters (parameters with very limited chance of exceeding the regulatory limits) or even declaration as WFT products (all parameters fall within the specified regulatory framework). The testing consists of:

- *characterization of the product or product group*
- *evaluation of compliance as outlined in the scheme*
- *designation as WFT for parameters, WFT for product group or FT classification*
- *identification of compliance test for product group*

There is already a significant amount of data available. These data can be used as basis for judgement of WT, WFT or FT status. Based on the data presented in Annex A and B such evaluation can be made as example for both a monolithic and for a granular material.

Examples
In Annex A and B data are given which as an illustration can be compared with regulatory criteria as laid down in the Building Materials Decree [9]. The test data can be judged against the service life conditions by verifying of test data of respectively percolation test and tank test against corresponding regulatory criteria.

Table 2.2 *Example of evaluation of cement mortar for WFT (basis of reference BMD, 1995)*

Element	Service life	Recycling (bound)	Recycling (unbound)
Ba	WFT	WFT	Test
Cr	WFT	WFT	Test
Mo	WFT	WFT	Test
Ni	WFT	WFT	Only when pH < 9
Pb	WFT	WFT	WFT
SO4 as S	WFT	WFT	Test when pH < 10
Sb	Test (FREQ)*	Test	Test
V	WFT	WFT	Test

* If the specific condition of Sb release can be shown not to be relevant for a given production or the limit value for Sb is higher than the value in the BMD, it could be identified as WFT product.

Table 2.3 *Example of evaluation of MSWI bottom ash for WFT (basis of reference BMD, 1995)*

Element	Service life	Recycling (unbound)
Cd	WFT	Test when pH < 8
Cr	WFT	Test (only when reheated)
Cu	Test	Test
Mo	Test	Test
Ni	WFT	Test when pH < 8
Pb	WFT	WFT
SO4 as S	WFT	WFT
Sb	Test (FREQ)	Test
Zn	WFT	WFT

Given the requirement to test this material for at least 3 parameters, this will classify as a FT material.

2.8 Further testing (FT)

The approach as outlined in the scheme presented in Figure 2.5 forms the basis for evaluation of construction products leading to a classification as FT product. Such materials will be exempt from CE marking. This classification implies that the material is produced with release properties relatively close to the limit value. This will generally lead to a system of control of delivered batches. As soon as an FT material does not comply, it is not acceptable for use. Also for FT materials the number of parameters that need to be measured can be reduced depending on the initial characterisation and demonstration that data from different production dates fall within a certain bandwidth.

2.9 Characterization – quick testing

Relationship
Given the fact that characterization is the first step needed to be able to judge the environmental properties of any construction product, a subsequent step is the identification of tests that are suitable as quick test for granular and monolithic materials from the various product families. It is important that quick test results are not judged on their own, but in context with the associated characterization information. This implies that a widely assessable European database of basic material properties is very useful to ensure a common basis of reference. Once the basic information for a material class or category is available, the testing can be limited to quick testing (for details on how to handle in case of deviations see section 5).

Selection of quick test for monolithic material
In the case of a monolithic material the most suitable option is to perform the first few steps of the procedure [6] only, which can be done in a day. In this manner the test result is directly linked to the more elaborated procedure. In most cases, the leaching behaviour as obtained in the elaborate test will show, if there are limitations to this approach (e.g. wash-off effects, delayed release). Part of the proposed monolith quick leaching test in CEN/TC 292/WG2 [10] is based on this concept.

Selection of quick test for granular material
In case of granular material there is the option to apply a batch test at L/S=10 or to collect similar to the approach for the monolithic material only the first two fractions of a column test. This choice may be linked to the subsequent use of the data. In case the emphasis for the application lies on very low liquid solid ratios in the application, the latter approach may be more relevant.

On the other hand the reproducibility and repeatability (within and between lab variability) may be less in the analysis of the first fractions of the column as in the batch test the larger liquid to solid ratio may lead to less variability. From the validation study of CEN/TC 292 batch leaching test EN12457 [11,12], a measure of the within and between lab variability can be obtained for the batch procedure. In a few cases, a distinct difference has been noted between a batch L/S=10 test and a percolation test [4]. This could for instance be attributed to a significant difference in pH history between column and batch. In the column initially a low pH occurred leading to a high metal release and subsequently the pH dropped to alkaline conditions. In the batch procedure the pH never was mildly acidic and therefore the realistic initial high release was not picked up in the batch test. Generally, the relationship between a batch and column test is good, when the pH changes during the percolation test are not very large (most cases).

Example
In Figure 2.9 a typical example of the relationship between batch and column test is given. The uncertainty for the batch test on BA-A is derived from the validation work on EN 12457-3 (coded CEN3) [13]. The cumulative leaching from MSWI bottom ash in a percolation test reflects that initially the pH is higher, but starts to drop significantly in the course of the leaching tests. With the drop in pH the leachability of Zn decreases leading to an almost flat cumulative release curve. The data from the same sample are consistent with the full characterisation test data. Even de samples from other production dates are quite consistent with the observed behaviour of sample BA-A. This is illustrative of a more common observation that the leaching behaviour of MSWI bottom ash in spite of its heterogeneous nature is quite systematic in spite of large variations in leachability of specific elements as a function of pH. This points at the same solubility controlling minerals or phases dictating release from MSWI bottom ash.

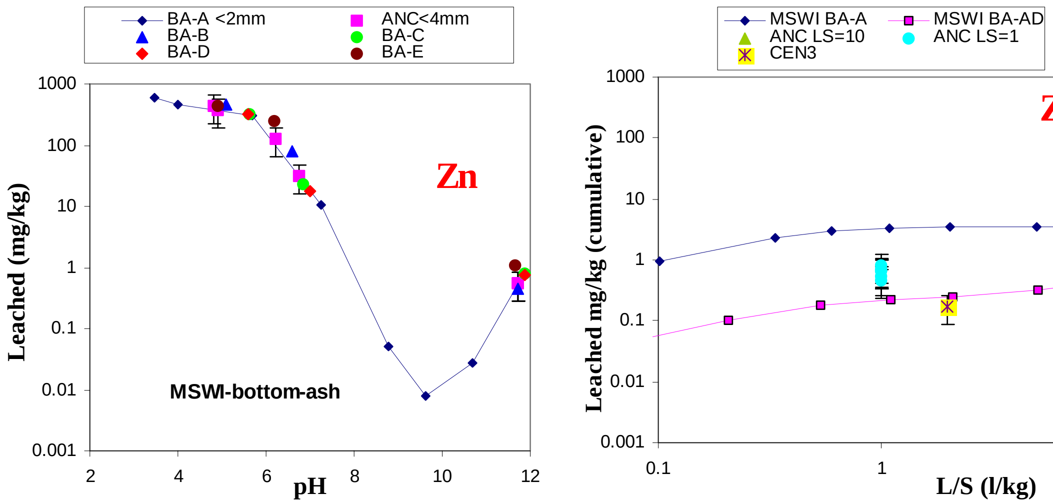


Figure 2.9 *Relationship between a batch test and characterisation tests - pH dependence test (PrTS 14429) and a percolation test (PrTS14405). BA-B, C, D and E are other bottom ash samples from the same facility, but other production times. The uncertainty for the batch test on BA-A is derived from the validation work on EN 12457-3 (coded CEN3) [13]*

In Annex E, the relationship between short and more elaborate test is given for more parameters on the same MSWI bottom ash.

The pH dependence test [3] data can be used for chemical speciation modelling. When the solubility controlling phases can be identified, prediction of leaching behaviour under other conditions than those actually measured can be made. This is a very recent development, which also will allow description of release in different application scenarios taking into account external influences (oxidation, carbonation, hydrological variations, changes in liquid solid ratio, redox changes, etc.). In Annex C, the chemical speciation modelling of a crushed blended cement mortar and MSWI bottom ash is given. In one modelling run mineral saturation indices are calculated for individual parameters to identify, which mineral phases potentially play a role. The role of dissolved organic matter (DOC), which is highly relevant in metal mobilisation in MSWI bottom ash, can be evaluated as well. The identified mineral and the metal availabilities are used for the release prediction of the pH dependence test results using the same speciation reactive transport model Orchestra [14]. A good match points at an apparent adequate prediction of controlling phases. This material characterisation information can be used in subsequent modelling of dynamic release processes such as in column leaching and tank leaching tests. Finally, the same mineral and sorption parameter data can be used for scenario modelling, which goes well beyond the commonly applied Kd principle (see impact modelling in part 1).

2.10 Compliance with regulations

For compliance with regulations a few options are available:

- Comparison with generic application criteria derived from impact evaluations for a limited number of different release scenarios as described in Part 1 (7 scenarios), which are linked to a specific generic test method (e.g. column test, tank test or related short test methods) [15].
- Evaluation of impact through scenario modelling taking into account more detailed and possibly site-specific information to evaluate impact relative to specific points of compliance specified criteria at this target [16].

2.11 Testing of release in different life cycle stages of a construction product

Life cycle

In the CPD only service life of a material is covered. At several occasions it has already been stated that it may be important from a sustainable development perspective to take recycling and end-of-life conditions into account to ensure that for an alternative material, for which there are concerns in the recycling stage (for instance in unbound application), proper measures are taken to avoid impact in such a subsequent life-cycle. The previously described characterisation provides a basis for judging the potential long-term behaviour. If during service life there is no environmental problem will not mean the material is safe for the long-term. If a material poses a problem in recycling and end-of -life then it is crucial that the later life cycles are taken into account from a precautionary principle approach. Obviously, the judgement cannot be a conservative estimate, so positive changes in material properties should also be taken into account (e.g. carbonation, re-mineralisation).

Basis for judgement of other life cycle stages

The pH dependence-leaching test described as an important part of the characterisation of monolithic construction materials provides the basis for a first evaluation of the recycling as unbound material or end-of life condition. This judgement is based on the size reduction in combination with a often neutral to light alkaline condition of a fully carbonated construction debris. The evaluation is limited, as the common particle size distribution of construction debris is not taken into account. This part of the evaluation is still in development.

In Figure 2.10 the building cycle is shown with an illustration of the type of tests that are suitable at specific stages in the building cycle. The central information flow can be developed as a database system for easy access to already existing test data for a given material type or class.

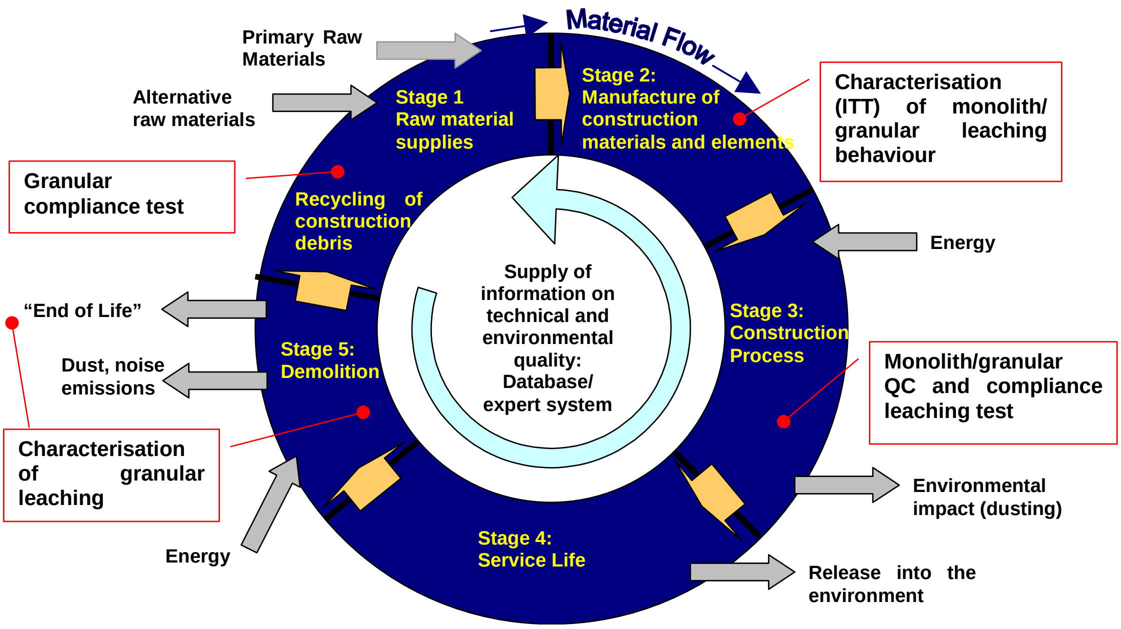


Figure 2.10 *Characterisation and compliance testing in different stages of the building cycle*

2.12 Relevance of a database/expert system for construction product data

As has been stated compliance test data should be presented in context with characterisation data to allow proper judgement of acceptability. This data may be taken from work carried out elsewhere. This implies that characterization data should be readily assessable. Preferably, through a web-based tool. When data from the public domain and anonymous data from industry can be combined to provide a reference base for a range of important construction products, like the cement mortars presented in Annex A, then a decision can be taken that a product produced in country A meets the data set build up in country B, C and D, provided the leaching character can be described as being systematic.

The data shown in Annex A, B and C have been generated using such a system. The impact evaluation as given in Part 1 is an extension of the modelling capabilities that form the basis for the modelling as shown in Annex C.

2.13 Conclusions

- As indicated in part I and further supported here by means of examples for a monolithic and a granular material, the characterisation methods proposed - pH dependence leaching test for speciation and time dependent release behaviour through, respectively, a percolation test and a tank leach testfor monolithic - and granular material - allow a wide range of conditions and scenarios to be covered. One set of characterisation data for a given material can therefore be applied for different uses, thus avoiding additional testing.
- As illustrated for cement mortar from world-wide origin and for MSWI bottom ash the leaching behaviour of these materials is not as highly variable as might be inferred from single step leaching test data. The solubility controlling mineral phases and sorption processes are very similar for a given material and vary by the element availabilities as obtained from a pH dependence leaching test at low pH.

- The testing of constituents can not be used to provide a conclusion on the release behaviour of construction products. This implies that for compliance with ER 3 criteria only final products need to be judged.
- The characterization test results provide the basis for development of regulatory criteria, a basis of reference for quality control and compliance testing, and basis for identifying potential options for product improvement.
- The relationship between characterization and compliance leaching tests should be optimised to be able to directly apply criteria developed using the characterisation test data through scenario descriptions to criteria for compliance test data. As illustrated for a wide range of parameters in a rather heterogeneous matrix this is an achievable goal.
- The characterisation also provides a means to evaluate release in recycling and end-of life scenarios materials. In this context for construction particle size reduction, carbonation (cement-based materials), re-mineralisation and oxidation are of importance.
- A scheme for deciding about WT, WFT by parameter, WFT for a construction product and FT has been set up. The WFT classification for a product group or material is relevant when all regulatory parameters for that product meet the WFT criteria for all individual parameters. To decide about WFT for a product group or material type, the bandwidth of release parameters for that product should meet the WFT criteria for all individual parameters.
- As the release level that corresponds to WFT is a function of regulatory criteria, factors are needed between the acceptable release level for WFT and the regulatory limit.
- A database/expert system for leaching and composition data of construction product will help to avoid unnecessary duplication of work. Already a rather extended dataset is available for a large number of the most common construction products. When such information is anonymously made available to a central European database, this dataset can be used as reference and justification for limited testing.

2.14 References

[1] Construction Products Directive (89/106/EEC)

[2] Sloot, H.A. van der, L. Heasman, & P. Quevauviller (1997): *Harmonisation of leaching /extraction tests*. Elsevier Science B.V., Amsterdam.

[3] Characterization of waste – leaching behaviour test – TS14429 - Influence of pH on leaching with initial acid/base addition. CEN/TC 292 Working Group 6. 2004. Characterization of waste – leaching behaviour test – prTS 14997 - Influence of pH on leaching with continuous pH control.

[4] Characterisation leaching test - TS14405 - Percolation test - Upflow. CEN/TC 292 Working Group 6. 2004.

[5] Characterization of waste – leaching behaviour test – Dynamic leach test for monolithic materials. CEN/TC 292 Working Group 6. Work item in preparation 2005.

[6] NEN 7345 (1994): *Determination of leaching from monolithic construction materials and waste materials by means of a diffusion test*. October 1994.

[7] NVN7347 - Compacted granular Leach Test. NEN, 1998.

[8] EN – 197- (2000): *Cement: Part 1: Composition, specifications and conformity criteria for common cements.* 1 June 2000.

[9] Building Materials Decree. Staatsblad van het Koninkrijk der Nederlanden, 567, 1995.

[10] CEN TC 292 WG2 Monolith compliance leaching test WI292010.

[11] Compliance leach test (1996): Characterisation of waste. Leaching. Compliance test for leaching of granular waste materials. Determination of the leaching of constituents from granular waste materials and sludges. European Standard EN 12457 Parts 1-4.

[12] Sloot, H.A. van der, O. Hjelmar, J. Bjerre Hansen, P. Woitke, P. Lepom, R. Leschber, B. Bartet, N. Debrucker (2001): *Validation of CEN/TC 292 Leaching Tests and Eluate Analysis Methods PrEN 12457 part 1- 4*. ENV 13370 and ENV 12506 in Co-operation with CEN/TC 308. 2001. ECN-C--01-117.

[13] Characterisation of waste - Methodology guideline for the determination of the leaching behaviour of waste under specified conditions. EN 12920, CEN/TC 292. 2005.

[14] Meeussen, J.C.L. (2003): *ORCHESTRA: An object-oriented framework for implementing chemical equilibrium models*. Environmental Science and Technology, 2003**,** *37*, 1175-1182.

[15] Sloot, H.A. van der & Dijkstra, J.J. (2004): *Development of horizontally standardized leaching tests for construction materials: a material based or released based approach?* ECN-C--04-060; Energy Research Centre of the Netherlands (ECN): Petten, The Netherlands, 2004.

[16] Kosson, D.S., H.A. van der Sloot, F. Sanchez & A.C. Garrabrants (2002): *An integrated framework for evaluating leaching in waste management and utilization of secondary materials*. Environmental Engineering Science (19) 3, 159-204.

3. CPD Topic 3 – Proposal for reference to ER 3 aspects in product standards and in CE marking

3.1 Introduction

Technical specifications – and in particular harmonized European standards – must provide the necessary ‘deemed-to-satisfy-procedures’ to demonstrate compliance with the relevant Essential Requirements (ER) as defined in Annex 1 of the Council-Directive (89/106/EC).

Since the ER 3 concerning ‘Hygiene, health and the environment’ concerns a wide variety of different construction products (Topic 1, Table 2), it is of great importance that procedures, laid down in harmonized European standards, are consistent and generally applicable. These procedures must provide a framework, which allows to assess all related construction products on a comparable basis. In addition these procedures must allow to deal with any product specific feature on a product by product basis.

European and Member States legislations e.g. transposed European legislations and national laws, regulations and administrative provisions in force on the European Market and addressing aspects related to the ER 3 should be documented in the ‘European Database on Regulated Substances’(http://europa.eu.int/comm/enterprise/construction/internal/dangsub/dangmain.htm).

The verification of compliance with requirements related to each of the relevant release scenarios must include compliance with any requirement (e.g. restrictions or bans of active use of ‘Regulated Substances’) resulting from this legislation, when and where it applies.

It is not within the scope of the harmonized European Standards to include these requirements, which very often are different from Member State to Member State. However, the objective of harmonized European standards must be to provide instruments to verify compliance with these requirements. Moreover, it will not be feasible to include the corresponding testing procedures for environmental properties within a product standard. This implies that proper reference must be made on *which* horizontal measurement/test standard has to be used for a given purpose and *how* the test results have to be interpreted. Horizontal measurement/test standards are worked out under the mandate ‘Development of horizontal standardized assessment methods for harmonized approaches relating to dangerous substances under the Construction Products Directive (CPD)’. After a general description of standardization and regulatory aspects regarding ER 3, a proposal how to incorporate ER 3 aspects in European Standards, exemplified for the European cement standard EN 197-1, is worked out.

3.2 Regulatory and Standardization Aspects

3.2.1 Regulatory aspects

Release scenario

The mandate on the development of horizontal standardized assessment methods for harmonized approaches relating to dangerous substances under the Construction Products Directive (CPD) addresses two distinct release scenarios to be taken in consideration:

- Release of Regulated Dangerous Substances from construction products into soil, groundwater and surface water.
- Release of Regulated Dangerous Substances from construction products into indoor air.

This study deals only with the first scenario considering the release into soil, groundwater and surface water. Specifications in product standards must respond to requirements defined in European or Member State Regulations and must show compliance with these regulatory requirements

Compliance Criteria in Regulations
Part 1 of this study shows the impact of the release of dangerous substances on soil and groundwater, proposes analytical models to assess this impact and provides the methodology to develop criteria to verify compliance with regulatory requirements – normally expressed in terms of immission limits at the point of compliance. Specifications on the leaching performance in product standards must be expressed in a way, that they can be correlated to these regulatory limits (see part 2).

3.2.2 Standardization Aspects

Type of product
In view of the assessment of the leaching performance it may be reasonable to distinguish between the following types of products:

- Constituents of materials, e.g. cement, water, additions, admixtures and aggregates for fresh concrete.
- Materials, e.g. mortar bars, concrete cubes.
- Products, e.g. concrete beams, concrete tubes, concrete slabs made from fresh concrete.

Compliance criteria address the product in contact with soil and groundwater. In the case of concrete the product in contact with soil and groundwater is often produced on site and could in this case only be assessed after construction. To allow an a-priory assessment, it is necessary to express conformity by means of criteria expressed for the materials used in the product or even for the constituents used for the materials. This requires defining conventional material and/or product compositions and corresponding test specimens (see Annex B to this chapter)

Conformity verification concept
The mandate on the development of horizontal standardized assessment methods for harmonized approaches relating to dangerous substances under the Construction Products Directive identifies two main procedures for the verification of conformity of construction products with criteria related to their release performance (see part 2). First the classification of construction products as products not requiring testing (WT-products) and second the verification through testing. This second procedure is again subdivided for products, which can be verified on the basis of Initial Type Testing (ITT) only, these products are called WFT-products (products without further testing) and for products, which are verified on the basis of a regime of further testing (FT-products).

Conformity verification Instruments
For products already identified as construction products under the Construction Products Directive, information on the constituents and possible additions and on the intended use of the product in view of relevant release scenarios should be included in the Standard. The description of the constituents and possible additions in the harmonized standard should be given in a way, to allow European and Member States regulations to identify through proper characterisation the product as WT-product or to classify the product through Initial Type Testing as WFT-product (see part 2).

WT-products are identified as such on the basis of a decision matrix based on product characterization, which may include speciation (contents and/or availability tests and leaching tests. The classification of WT-products furthermore takes account of the application specifications of the product in the intended use, which are often standardized in corresponding standards and of the practical experiences gained in laboratory tests and in practical applications (see Part 2 of this study). Guidance for expert bodies to propose WT classifications will be worked out by CEN under the above-mentioned mandate. This guidance needs to refer to horizontal standardized test procedures [characterization (contents, availability, leaching)], which may need to be specified in further detail for a given construction product.

WFT-products are verified on the basis of Initial Type Testing procedures, which similar to characterization testing may be based on contents and/or availability tests and on leaching tests. Corresponding product standards therefore have to refer to horizontal Initial Type Testing procedures, which may need to be specified in further detail for a given construction product.

FT-products are verified on the basis of conformity testing procedures, which normally are short-term leaching tests. Corresponding product standards therefore have to refer to horizontal conformity leaching tests, which may need to be specified in further detail for a given construction product.

If characterization tests, initial type tests or further testing (conformity tests) related to dangerous substances are necessary for a construction product, the corresponding harmonized testing standards must refer to specifications on:

- Sampling of representative materials, products
- Preparation of test specimens
- Curing of test specimens (if necessary)
- Preconditioning of test specimens (if necessary)
- Measurement/test methods
- Chemical analysis of the relevant dangerous substances

The measurement/test methods referred to in the product standard should use – as far as possible - horizontal test methods to be worked out under the mandate ‘Development of horizontal standardized assessment methods for harmonized approaches relating to dangerous substances under the Construction Products Directive (CPD)’.

Supporting Technical Reports

- Scenario Models to correlate product leaching parameters with regulatory compliance parameters (emission parameters, e.g. expressed as fractiles of the leaching measurements, correlated with regulatory compliance criteria, expressed in limit immissions at the point of compliance). In Part 1 seven relevant release scenarios for the release of dangerous substances from different construction products to soil and groundwater have been identified (Part 1, Table 1). Moreover, mechanistic models, in order to transfer tested release parameters on the basis of the transport of substances in soil and groundwater to a certain point of compliance (POC), as required in European and/or Member States Regulations, are described. A wide variety of different construction products can be related to one or more of the identified relevant release scenarios. On this basis the responsible product TC can select the one or more release scenarios that are representative for the intended use of the specific construction product in its actual applications with its associated test methods.
- Decision matrix as guidance for expert bodies to classify WT-products.

3.3 Example for reference to ER 3 aspects in product standards and in CE marking

Proposal for the incorporation of ER 3 aspects into the European cement standard EN 197-1 (Cement – Part 1: Composition, specifications and conformity criteria for common cements).

Clause 1 Scope
The sentence '*Necessary durability requirements are also given*'**.**
should be extended to:
'*Necessary durability requirements and requirements regarding to hygiene, health and the environment are also given*'.

Clause 5 Materials
Based on characterisation relevant constituents (possibly related to specific alternative materials used) with regard to ER3 can be specified.

Clause 7 Mechanical, physical, chemical and durability requirements
should be extended to:
Clause 7 Mechanical, physical, chemical, durability requirements and requirements regarding the release of dangerous substances

A new clause '7.5 Requirements regarding the release of dangerous substances'
to be developed by CEN TC 51

3.3.1 Proposal for Annex B (normative)

Annex B
(normative)

Release of dangerous substances

B.1 Scope
This scheme outlines a testing scheme for cements using reference concrete matrices wherein the release of dangerous substances from the tested concrete constituent can be determined. This scheme may serve as reference as well for characterization as for initial type or further testing.

B.2 Sampling
The method used to take and prepare the cement lab-sample shall be in accordance with the relevant sampling standard EN 196-7

B.3 Preparation of test specimens
B.3.1 Concrete constituents
B.3.1.1 Aggregate

If not otherwise specified natural normal-weight aggregate conforming to EN 12620 should be used. The requirements for grading and water absorption should conform to EN 480-1.

Note Eventually additional requirements must be specified in the relevant CEN TC, e. g. TC 154. [e.g. TOC content of the reference aggregate to be limited]

B.3.1.2 Cement
Cement according to EN 196-7.

B.3.1.3 Mixing water
If not otherwise specified distilled or deionised water should be used.
B3.2 Concrete mix proportions

The minimum cement content should be XXX kg/m^3. The water cement ratio should be w/c = 0,XX. The concrete mix proportions should at least meet the minimum requirements of grade XXX in EN 206-1. The values should be developed by TC 51.

(Remark: In some Member States national regulations about concrete mix proportions exist. For example: In the DIBt-Guideline 'Part II: Concrete and Concrete's Constituents' [1] a cement content of 280 kg/m^3 and a water cement ratio of w/c = 0,60 - or the highest w/c ratio which is anticipated for the use - are laid down.)

B3.3 Moulds for test specimens

Moulds for preparing test specimens shall be made from alkali-resistant material that will not interfere with the concrete. If not otherwise specified the mould shall give a cube as test specimen with a total surface area of 6.0 ± 0.6 dm^2. If steel moulds are used the joints should not be coated with any wax, oil or grease to achieve water tightness. The use of release agents is not permitted.

B3.4 Concrete mixing and compacting procedure

If not otherwise specified the concrete constituents shall be conditioned and mixed in accordance with EN 480-1 at a temperature of 20 ± 2 °C. The filled moulds shall be compacted in accordance with EN 12390-2.

B.4 Curing of test specimens

After compacting the moulds are covered with an impermeable material, which does not react with the fresh concrete, and transferred to a constant temperature/constant humidity cabinet or an incubator containing a tray of water. Maintain the test specimens at a temperature of 20 ± 2 °C and a humidity > XX % for X days.

After curing for X days, the specimens are demoulded and weighted to an accuracy of ± 10 g and then placed in sealed polyethylene bags. The specimen are stored at a temperature of 20 ± 2 °C for further XX days. The values should be developed by TC 51.

(Remark: In some Member States national regulations about curing of test specimens exist. For example: In the DIBt-Guideline 'Part II: Concrete and Concrete's Constituents' [1] a curing for 2 days and a further storage time of 54 days is laid down. Depending on the strength development of the concrete, a different storage period, which must not however exceed 91 days, can also be specified.)

B.5 Preconditioning of test specimens

For the common use of cementitious materials in contact with soil and groundwater a preconditioning seems not to be necessary. However, for special applications a pre-conditioning of the test specimen may be laid down by the experts of the responsible TC.

B.6 Measurement/test methods

Based on the intended use as specified by the experts of the responsible TC with their specific knowledge about the product, the appropriate measurement/test method can be selected from the defined set of methods associated with a limited set of specified exposure scenarios.

For concrete tank leaching tests (own pH) are recommended to define leaching characteristics of e.g. concrete in contact with soil and groundwater. Under the mandate 'Development of horizontal standardized assessment methods for harmonized approaches relating to dangerous substances under the Construction Products Directive (CPD)' a long-term (several weeks) horizontal tank leaching test should be developed for characterization or initial type testing (characterization test, IT test). A simpler test on the basis of the test used for characterization or IT, e.g. a horizontal short-term (one or two days) tank leaching test with a reduced range of analytical parameters should be developed as conformity test for the case of Further Testing (FT).

B.7 Chemical analysis of the relevant dangerous substances

The dangerous substances in the eluates, which have to be analysed can be derived by the experts of the responsible TC, on the basis of the regulatory requirements (national or European) and the specific knowledge about the product as obtained from (prior) characterisation. For the analysis European analytical methods, as given in the following table for some elements, should be used.

Table 3.1 *Examples for analytical methods*

Regulated substances	Analytical method
Arsenic (As)	EN ISO 11969, EN ISO 11885
Cadmium (Cd)	EN ISO 5961-HA2/HA3, EN ISO 11885
Chromium (Cr_{total})	EN ISO 1233-HA3/HA4, EN ISO 11885
Chromate (Cr VI)	EN ISO 10304-3
Cobalt (Co)	EN ISO 11885
Copper (Cu)	EN ISO 11885
Lead (Pb)	EN ISO 11885
Nickel (Ni)	EN ISO 11885
Zinc (Zn)	EN ISO 11885

(Remark: In some Member states national regulations about the chemical analysis of the relevant dangerous substances exist. For example: According to the DIBt-Guideline 'Part II: Concrete and Concrete's Constituents' [1] the elements arsenic, cadmium, chromium (total), chromate (VI), cobalt, copper, lead, nickel and zinc have to be analysed in the eluates of the German long-term leaching test (leaching time 56 days))

(Remark: In the case of accepted models describing the immissions in the function of the tested emissions - e.g. point of compliance, allowed threshold values for immissions etc. - the emissions measured in the release test can directly related to the allowed immission values.)

3.4 CE marking symbol

An example for the incorporation of dangerous substances into the CE marking symbol is given in prEN 450-1: 2004 (E) 'Fly ash for concrete – Part 1: Definition, specifications and conformity criteria'.

In this standard the following information is added to the **CE marking symbol:**
Dangerous Substance: NL, F[1)]
[1)] Abbreviation of the name of the country where the fly ash complies with national regulation.

The 'No performance determined' (NPD) option may be used when and where the characteristic, for a given intended use, is not subject to regulatory requirements in the Member State of destination.

3.5 References

[1] DIBt - Guideline: Assessment of the effects of construction products on soil and groundwater, Part II: Concrete and Concrete's Constituents, Deutsches Institut für Bautechnik - DIBt -, Berlin, to be published.

[2] ECRICEM II report Environmental criteria for cement-based products - in preparation 2005.

Appendix A Intented use scenarios

CONSTRUCTION PRODUCTS DIRECTIVE (CPD)

Legend

Green	One horizontal standard for assessing emissions in all materials
Dark green	Additional method for assessing the same properties as in characterizatio
Magenta	At least more than one standard/ method needed
Yellow (?)	Not yet sure if emissions are relevant
White	Blank cell indicates no action in relation to this property is needed
Red	Currently outside scope of CPD, however important in the long term

Test methods shown in this table:

prEN14429	pH-dependence test, on granular or size-reduced material
prEN14405	column test, on granular material
EN12457-2	batch test (natural pH)
EN12457-3	serial batch test
WI-292040	dynamic monolith leaching test (DMLT, tank test)
WI-292010	compliance test for monoliths
EN1250	Tank test for preserved wood

(MODULAR) PROPERTIES FOR CONSIDERATION IN RELATION TO REGULATED SUBSTANCES IN CONSTRUCTION PRODUCTS

no.	Main aspect Target Sub topics Type Regulatory aspect PRODUCTFAMILIES IN CONSTRUCTION	Release Soil & groundwater Granular materials Characterization	 Compliance	 Monolithic/plate materials Characterization	 Compliance	 "End of life" size-reduced	comments
		Soil protection, surface water quality, groundwater quality					
1	Aggregates	PrEN14405 PrEN14429	EN12457-2			PrEN14429(pH=7) EN12457-2	Neutral pH is the most likely end stage after use of the product
2	Aggregate in concrete (bound)			WI-292040 PrEn14429	WI-292010	PrEN14429(pH=7) EN12457-2	idem
3	Aggregate in road base (unbound)	PrEN14405 PrEN14429	EN12457-2			PrEN14429(pH=7) EN12457-2	idem
4	Aggregate as structural fill (unbound)	PrEN14405 PrEN14429	EN12457-2			PrEN14429(pH=7) EN12457-2	idem
5	Cements, Building limes and other hydraulic binders #						see remark below; only the final product is tested, not the ingredients themselves.
6	Concrete, mortar, Grout and related products			WI-292040 PrEn14429	WI-292010	PrEN14429(pH=7)	Neutral pH is the most likely end stage after use of the product
7	Construction adhesives	?	?			?	maybe of importance when used outdoors or in end-of-life stage.
8	Curtain walling	?	?			?	maybe of importance when used outdoors or in end-of-life stage.
9	Doors, WIndows, shutters, gates and related building hardware			WI-292040 PrEn14429	WI-292010	?	E.g., galvanised products such as gates
10	External thermal insulation			WI-292040 PrEn14429	WI-292010	?	
11	Fire stopping, fire sealing and fire protection products	?	?				
12	Fixed fire fighting systems	?	?				
13	Floorings			WI-292040 PrEn14429	WI-292010	EN12457-2	If outdoors, or otherWIse in constact WIth (rain)water, this might be of importance
14	Geotextiles			WI-292040 PrEn14429	WI-292010		
15	Glass products						
16	Gypsum products	PrEN14405 PrEN14429	EN12457-2			EN12457-3	WIth column test/2-step leaching test, the amount of leachable gypsum can be estimated
17	Internal & external wall and ceiling finishes			?	?		
18	Internal partition kits			?	?		
19	Light composite wood based beams and columns			?	?		
20	Liquid applied waterproofing kits			WI-292040 PrEn14429	WI-292010		During and after hardening, this might be relevant
21	Masonry and related products			WI-292040 PrEn14429	WI-292010	EN12457-2	
22	Membranes			?	?		
23	Metal anchors for concrete						This is likely to be not of importance.
24	Metal injection anchors for use in concrete for fixing lightweight systems						This is likely to be not of importance.
25	Non-load bearing permanent shuttering kits					?	maybe only relevant during end-of-life
26	Pipes, tanks and ancillaries not in contact WIth water					?	maybe only relevant during end-of-life
27	Plastic anchors for use in concrete and masonry						This is likely to be not of importance.
28	Post-tensioning kits for pre-stressing of structure						
29	Prefabricated stair kits						
30	Reinforcing and pre-stressing steel for concrete						
31	Road construction products	PrEN14405 PrEN14429	EN12457-2	WI-292040 PrEn14429	WI-292010	PrEN14429(pH=7) EN12457-2	Many materials can be used
32	Asphaltic products	PrEN14405 PrEN14429	EN12457-2	WI-292040 PrEn14429	WI-292010	EN12457-2	may contain high concentrations of organic contaminants such as PAH, modified leaching protocols?
33	Roof coverings, rooflights, roof WIndows an ancillary products			WI-292040(kin) PrEn14429	WI-292010		Zinc or lead used on roofs, gutters etc.
34	Sanitary appliances					?	ceramic material, maybe only important during end-of-life
35	Self-supporting transluscent roof kits						considered not of great importance
36	Space heating appliances						This is likely to be not of importance.
37	Structural bearings						This is likely to be not of importance.
38	Structural metallic products	PrEN14405 PrEN14429	EN12457-2			EN12457-2	When used outdoors, this might be of importance (e.g., galvanised products)
39	Structural timber products (preserved)			PrEn14429 WI-292040 EN1250	WI-292012		Preserved timber products; during e.o.l. preservations might be lost
40	Systems of mechanically fastened flexible roof water proofing membr	PrEN14405 PrEN14429	EN12457-2	PrEn14429 WI-292040	WI-292010	EN12457-2	Might be asphaltic products, different testing protocols needed
41	Thermal insulating products					EN12457-2	glass-fiber products; sometimes treated with e.g. flame retardants, relevant for end-of-life
42	Timber frame and log fabricated building kits			PrEn14429 WI-292040	WI-292010		Preserved timber products; during e.o.l. preservations might be lost
43	Waste water engineering products (concrete?)			PrEn14429 WI-292040	WI-292010	PrEN14429(pH=7)	Emissions possible to surface/groundwater
44	Wood based panels			PrEn14429 WI-292040 EN1250	WI-292010		Preserved timber products; during e.o.l. preservations might be lost
45	Drinking water pipes (concrete)			WI-292040 PrEn14429	WI-292010, ATA	PrEN14429(pH=7)	Emissions possible to drinking/surface/groundwater and also to soil

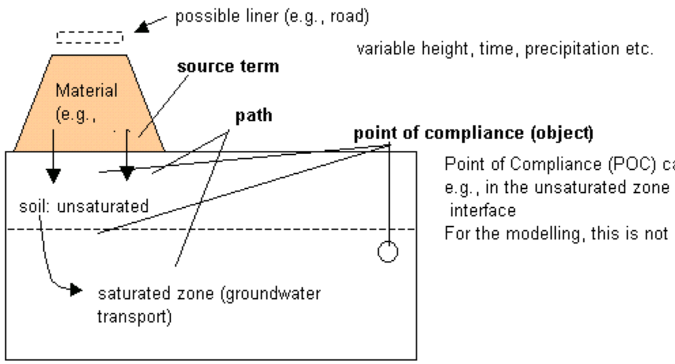
Footnotes:
& Characterisation or initial type testing
# Always tested as final product (concrete, mortar,etc)

A.1 Scen1 Granular soil

Scenario : percolation through a granular materi **Conceptual model:**

exposed to rainfall, leaching to soil/groundwater

*road base
*landfill
*structural fill embankment
*end of life of monolith products (size reduced)
* ..



Point of Compliance (POC) can be chosen anywhere; e.g., in the unsaturated zone or the soil-groundwater interface
For the modelling, this is not different.

Dominant leaching mechanism in scenario

Dominant transport mechanism	Percolation dominated; exchange through interpore diffusion possible
Dominant chemical mechanisms	wash-out, solubility control, sorption
Possible changes over time	Oxidation and carbonation

Relationship test results - criteria

simple modelling approach
model ready
one-dimensional source-term description
source term fitted by CSTR
assumptions on hydrology
assumptions on Kd
"impact" criteria = groundwater
limit value at POC
variable height/ time

advanced modelling approach
model ready
ORCHESTRA
Speciation and transport
1, 2 or 3 dimensional description of hydrology,
sections of the road with infiltration
and sections only affected by diffusion
More complex chemical changes e.g.
oxidation and carbonation

Necessary input from test results and/or database scan

Simple: *"kappa" fitted from percolation test

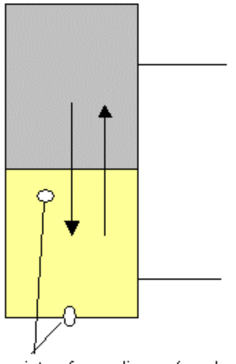
Advanced:
* Element spectrum measured for each pH
* buffering capacity curve (ANC)
* solid phase characteristics of material and soil
(organic matter, Fe, Al)

A.2 Scen2 Monol soil

Scenario : monolith in contact with soil

* Monolithic structures in contact with soil
(e.g. buildings, synthetic materials)
* Treated wood (directly in contact with soil)
* Pipes for transport of materials placed in soil (e.g., drinking water or sewer pipes)
*Grouts (after hardening)
*..

Conceptual model:



Monolith variable height, time, precipitation etc.

Monolithic structure; e.g. concrete, but also
synthetic materials (diffusion ontrolled release)
thickness can be varied: thin (rapid depletion) or thick (no depletion

Soil with characteristics allowed to
vary: moisture content, sorptive behaviour

soil

points of compliance (can be chosen anywhere)

Dominant leaching mechanism in scenario

Dominant transport mechanism
Diffusion dominated: in soil, the major transport mechanism is interpore diffusion

Dominant chemical mechanisms
in monolith: solubility control, availability; **in soil**: sorption, solubility control

Possible changes over time
carbonation at the interface, precipitation of other minerals at the interface
"sealing" of pores, thereby changing tortuosity

Relationship test results - criteria

simple modelling approach
model needs more development
analytical solution to diffusion
from monolith

assumptions on Kd in soil
"impact" criteria = groundwater
limit value at POC
variable height/ time

advanced modelling approach
model ready
ORCHESTRA
Numerical description of diffusion process
coupling with chemical speciation and transport
In the soil, transport through diffusion/convection
Sorption to organic matter and oxide surfaces

Necessary input from test results and/or database scan

Simple modelling approach:
Effective diffusion coefficient (pDe)

Advanced modelling approach:
Effective diffusion coefficient (pDe)
ANC curve, pHstat for wide spectrum of elements
both for the monolith and for the soil
(or: based on assumptions)

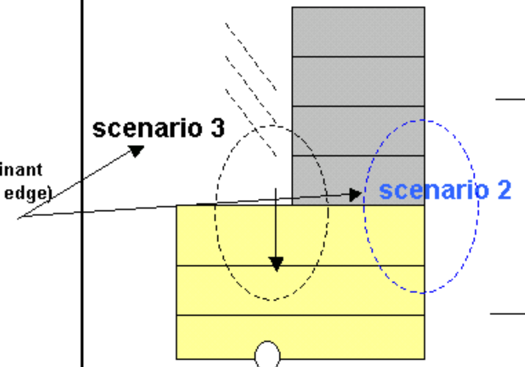
A.3 Scen3 Monolith runoff

Scenario : monolith runoff, in contact with soil

Conceptual model:

* Monolithic structures in contact with soil
(e.g. buildings, synthetic materials)
* Treated wood (rainfall)

The difference with scen 2 (monolith-soil) is the intermittent wetting of the surface exposed to the atmosphere, and the dominant water transport in the soil (convection dominated at the edge) Both scenario 2 and 3 can be combined, however.



Monolith variable height, time, precipitation etc.

Monolithic structure; e.g. concrete, but also synthetic materials (diffusion ontrolled release)

Soil with characteristics allowed to vary: moisture content, sorptive behaviour

soil

Dominant leaching mechanism in scenario

Dominant transport mechanism

Dominant chemical mechanisms

Possible changes over time

Diffusion dominated for the monolith; in soil, the major transport mechanism is convection
in monolith: availability (initial wash-off), on the long term, solubility control; **in soil**: sorption, solubility control
carbonation at the interface, precipitation of other minerals at the interface
"sealing" of pores, thereby changing tortuosity

Relationship test results - criteria

simple modelling approach
model needs more development
analytical solution to diffusion
from monolith + intermittent wetting
(does not contain levelling concentrations)
Analytical model Garrabrants (2002) is an option.
assumptions on Kd in soil
"impact" criteria = groundwater
limit value at POC
variable height/ time

advanced modelling approach
model needs more development
ORCHESTRA
Numerical description of diffusion process
& intermittent wetting
coupling with chemical speciation and transport
In the soil, transport through convection
Sorption to organic matter and oxide surfaces

Necessary input from test results and/or database scan

Simple: Effective diffusion coefficient (pDe)

Advanced:
Effective diffusion coefficient (pDe)
ANC curve, pHstat for wide spectrum of elements
both for the monolith and for the soil
(or: based on assumptions)

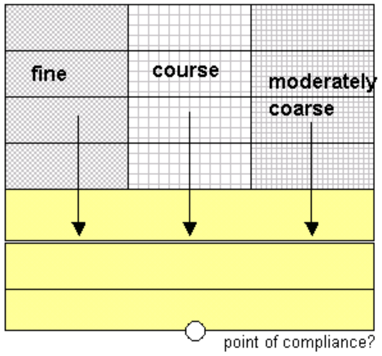
A.4 Scen4 Constr debris

Scenario : percolation through coarse or fine debris , in contact with soil

*** all end-of-life materials**
* Construction debris in contact with soil
(e.g. buildings, synthetic materials)
* (Synthetic) aggregates in contact with soil
* Coarse materials such as steel slag

Although source term is different, the transport in the soil is similar to scen 1 (granular-soil) or 2 (monolith_soil) depending on the particle size

Conceptual model:



Coarse and fraction: behaves like monolith (coarse) or granular (fine

Resulting percolate infiltrates in soil; from there, the scenario is similar to that of scenario 1(infiltration through convection)

soil

Dominant leaching mechanism in scenario

Dominant transport mechanism

In debris, diffusion or convection dominated (depends on particle size)
In soil, the major transport mechanism is convection

Dominant chemical mechanisms

in debris: availability (initial wash-off), on the long term, solubility control;
in soil, sorption, solubility control

Possible changes over time

carbonation at the interface of particles and at the interface with the soil,
precipitation of other minerals at the interface with the soil
"sealing" of pores, thereby changing tortuosity

Relationship test results - criteria

simple modelling approach
coarse debris: model needs more development
For "fine" debris, the model approach is similar to scen 1
analytical solution to diffusion
from monolith + intermittent wetting
(does not contain levelling concentrations)
Analytical model Garrabrants (2002) is an option.
assumptions on Kd in soil
"impact" criteria = groundwater
limit value at POC
variable height/ time

advanced modelling approach
coarse debris: model needs more development
For "fine" debris, the model approach is similar to scen 1
ORCHESTRA
Numerical description of diffusion process & intermittent wetting
coupling with chemical speciation and transport
In the soil, transport through convection
Sorption to organic matter and oxide surfaces

Effective diffusion coefficient (pDe)
ANC curve, pHstat for wide spectrum of elements
both for the monolith and for the soil
(or: based on assumptions)

Necessary input from test results and/or database scan

Effective diffusion coefficient (pDe)
Kappa estimated from column test (fine debris)

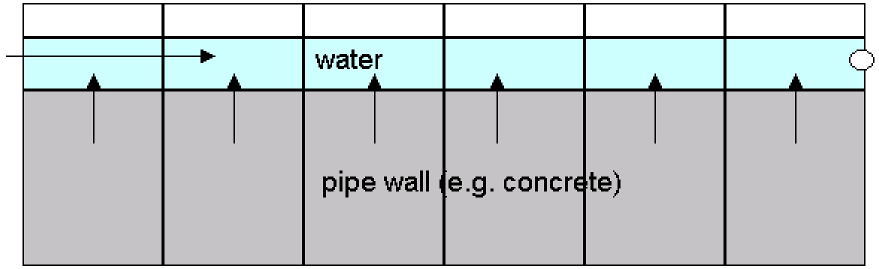
A.5 Scen5 DW pipes

Scenario : diffusion from DW pipe in transported wate

* (concrete) pipes for transport of drinking water
diffusion of contaminants from the pipewall into the transported water

Emission of contaminants from a pipe wall into the surrounding soil or groundwater is similar to scen 2 (monolith-soil)

Conceptual model:



(horizontal discretization in layers ->)

Dominant leaching mechanism in scenario
Dominant transport mechanism
Dominant chemical mechanisms
Possible changes over time

Pipe wall: Diffusion dominated for the monolith
Pipe wall: availability (initial stage: wash-off), on the long term, solubility control;
carbonation at the water interface, precipitation of other minerals at the water interface
"sealing" of pores, thereby changing tortuosity

Relationship test results - criteria

simple modelling approach
model needs more development
analytical solution to diffusion
from monolith + intermittent wetting
(does not contain levelling concentrations)
Analytical model Garrabrants (2002) is an option.
variable height/ thickness/time

advanced modelling approach
model ready
ORCHESTRA
Numerical description of wash-off, diffusion process
& intermittent wetting
coupling with chemical speciation and transport

Necessary input from test results and/or database scan

Simple: Effective diffusion coefficient (pDe)

Advanced: Effective diffusion coefficient (pDe)
ANC curve, pHstat for wide spectrum of elements

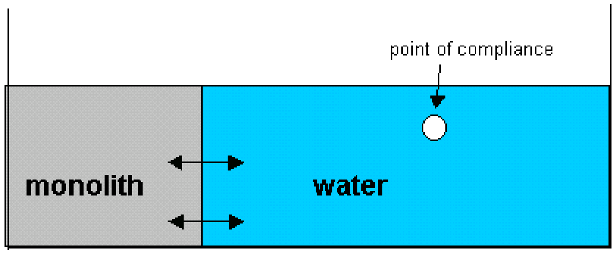
A.6 Scen6 Monol water

Scenario : monolith in contact with water

* Coastal works (wood, concrete, synthetic)
* Packing materials (food)
*..

This scenario is a simplified version of scen for DW pipes

Conceptual model:



Dominant leaching mechanism in scenario
Dominant transport mechanism
Dominant chemical mechanisms
Possible changes over time

Monolith: Diffusion dominated for the monolith
Monolith: availability (initial stage: wash-off), on the long term, solubility control;
carbonation at the water interface, precipitation of other minerals at the water interface
"sealing" of pores, thereby changing tortuosity
this will happen in relatively short time, in particular in salty media (seawater)

Relationship test results - criteria

simple modelling approach
model ready
analytical solution to diffusion
from monolith

advanced modelling approach
model ready
ORCHESTRA
Numerical description of diffusion process
coupling with chemical speciation and transport
In the soil, transport through diffusion/convection
Sorption to organic matter and oxide surfaces

Necessary input from test results and/or database scan

Simple modelling approach:
Effective diffusion coefficient (pDe)

Advanced modelling approach:
Effective diffusion coefficient (pDe)
ANC curve, pHstat for wide spectrum of elements
both for the monolith and for the soil
(or: based on assumptions)

A.7 Scen7 Plates

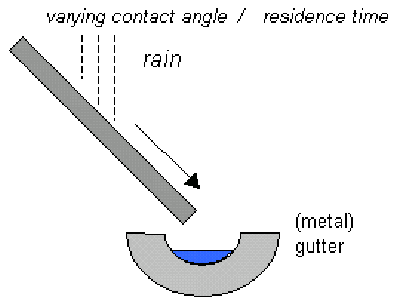
Scenario : runoff from metal plate material

* metal plating on roofs (zinc, aluminium, copper, lead)
* metal gutters
*..

The scenario differs from scen "monolith_runoff" because in this case, the release of plates is purely solubility controlled and not diffusion or wash-off.

For infiltration in soil, the scenario is similar to scen 3 (monolithic, infiltration in soil)

Conceptual model:



followed by infiltration in soil, or direct runoff to gutter/sewer

also here, the POC can be chosen anywhere; e.g. in the runoff water

Dominant leaching mechanism in scenario

Dominant transport mechanism: Runoff through rainfall

Dominant chemical mechanisms: Solubility control (constant release, depends on pH)

Possible changes over time: Formation of more stabile minerals over time; increase in surface area through dissolution/corrosion

<u>Relationship test results - criteria</u>

simple modelling approach

model ready

constant source,
released amounts only depend on exposed surface area, amount rainfall and time

infiltration in soil: see scen 1 (kappa, Kd)

advanced modelling approach

model ready

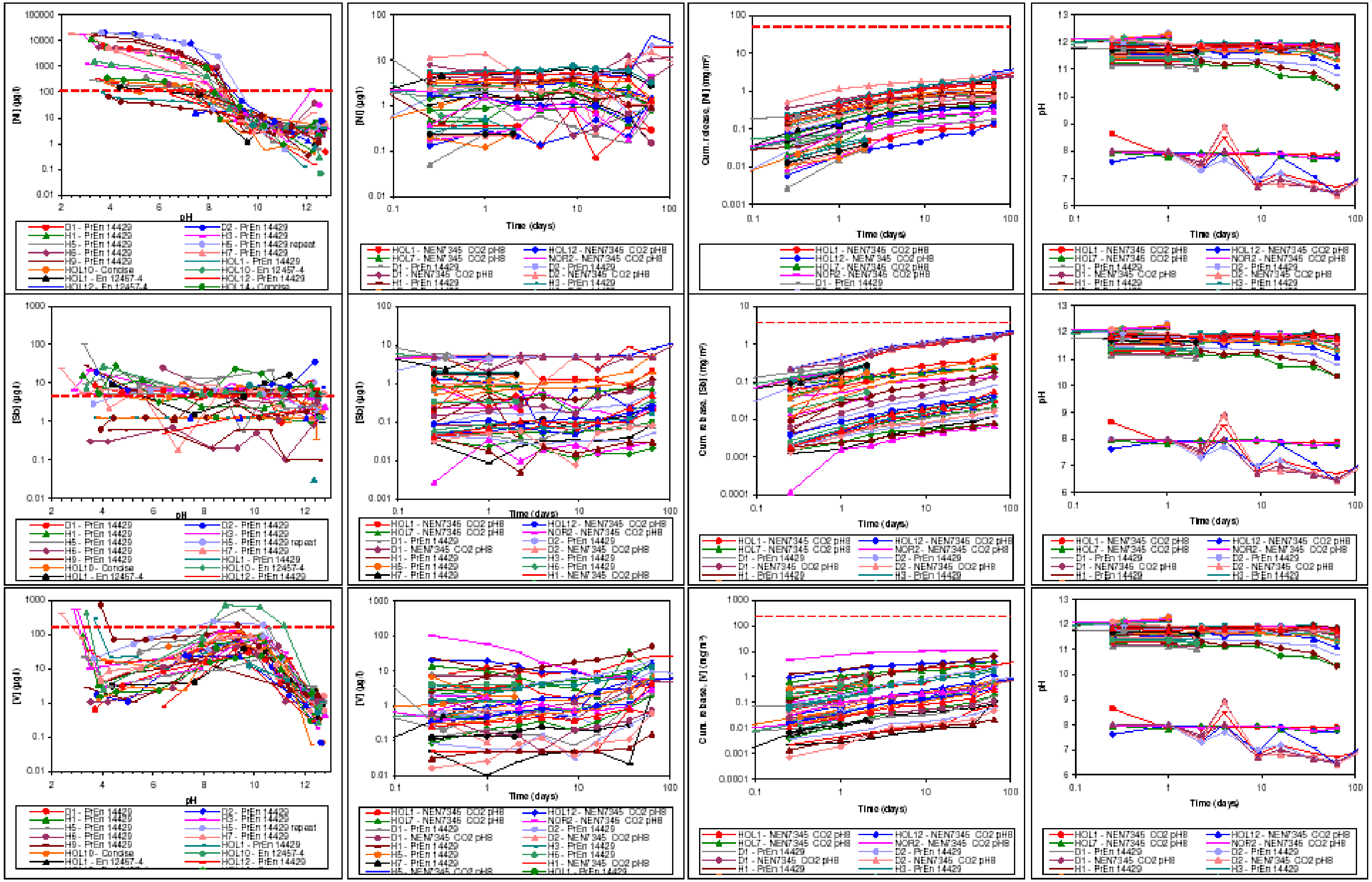
ORCHESTRA
Numerical description of solubility process coupling with chemical speciation and transport
In the soil, transport through diffusion/convection
Sorption to organic matter and oxide surfaces

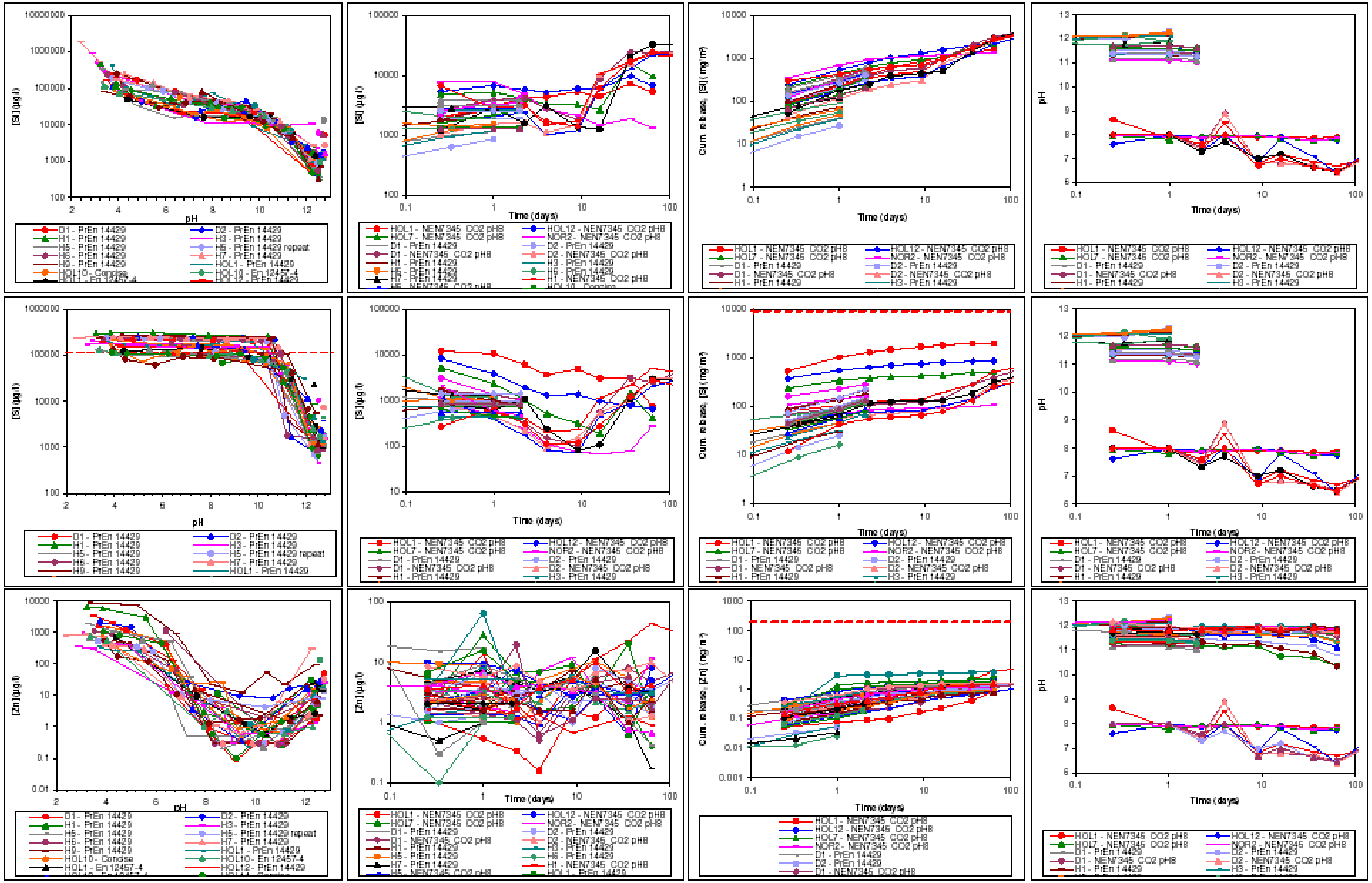
<u>Necessary input from test results and/or database scan</u>

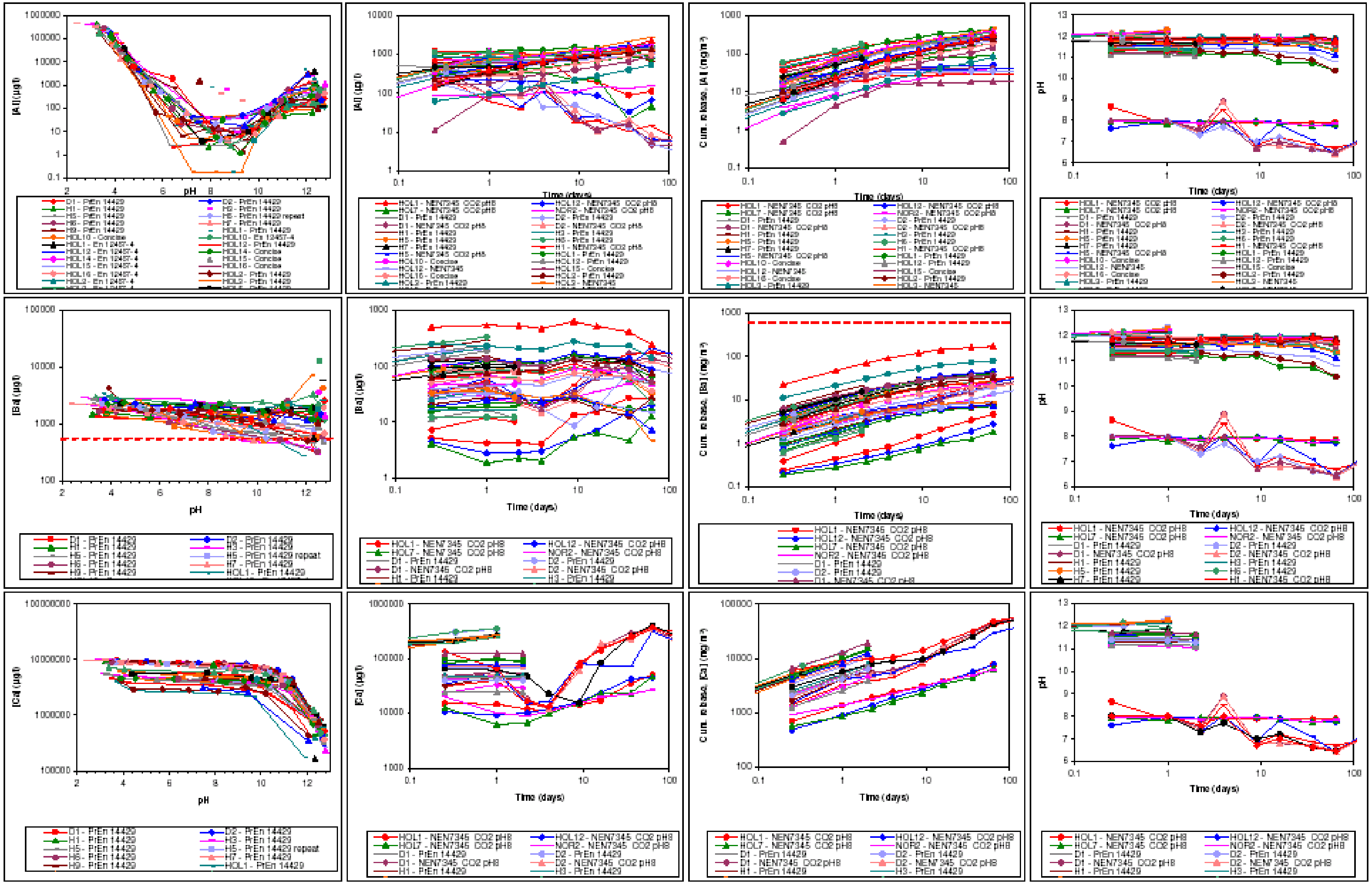
Effective diffusion coefficient (pDe)

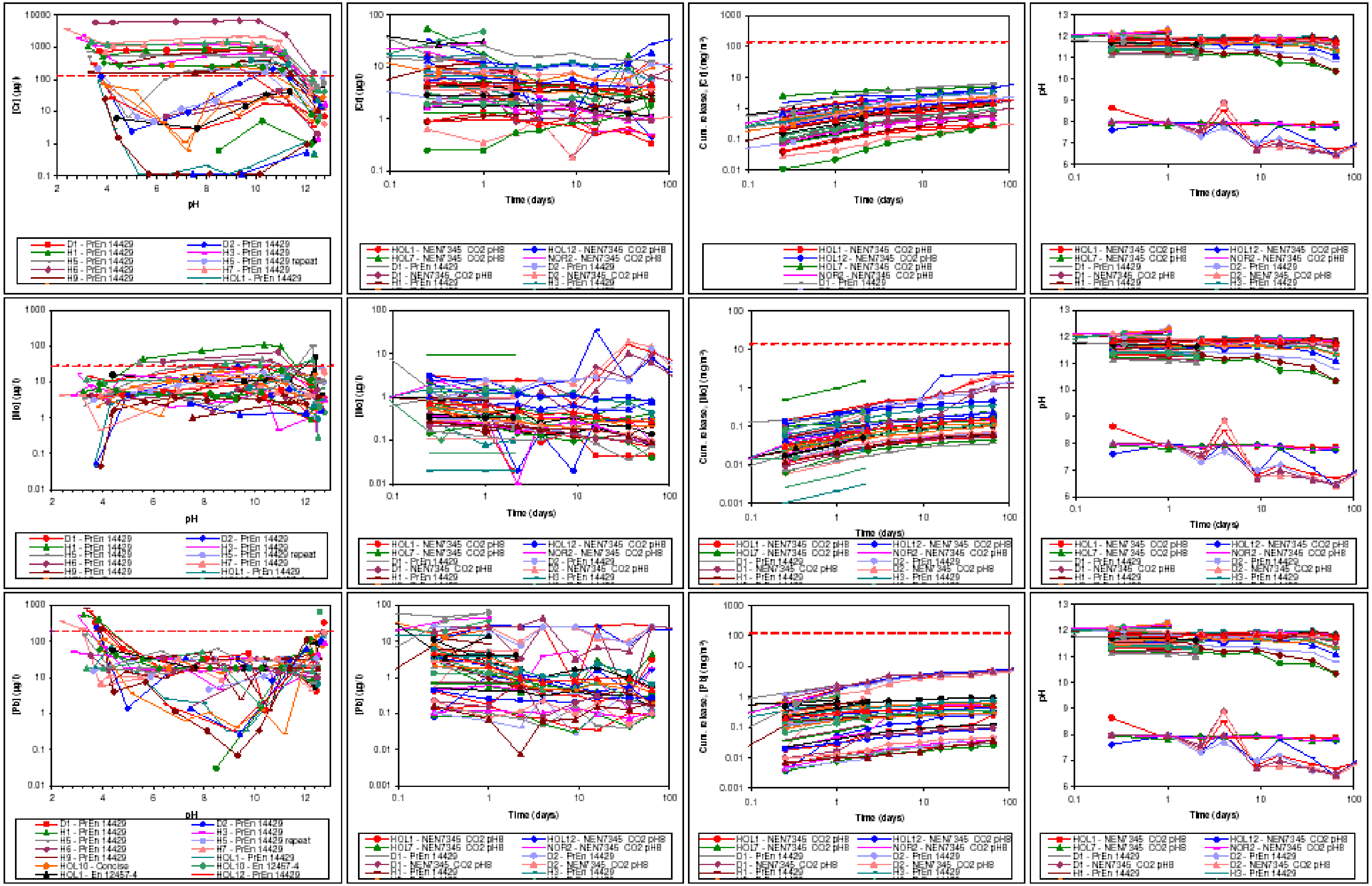
ANC curve, pHstat for wide spectrum of elements both for the plate and for the soil
(or: based on assumptions)

Appendix B Topic 2 Cement

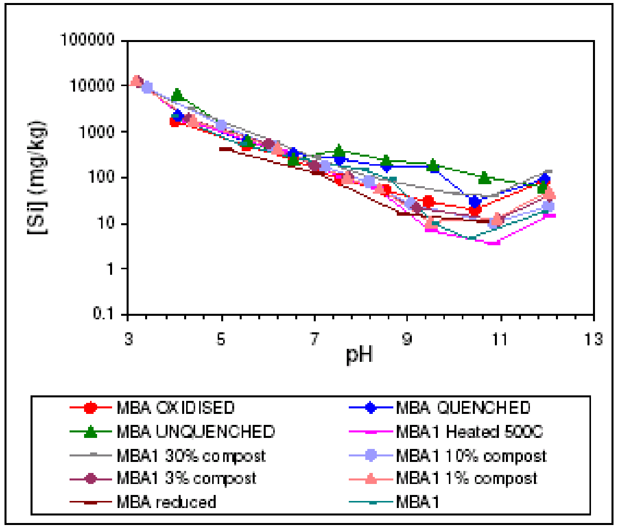


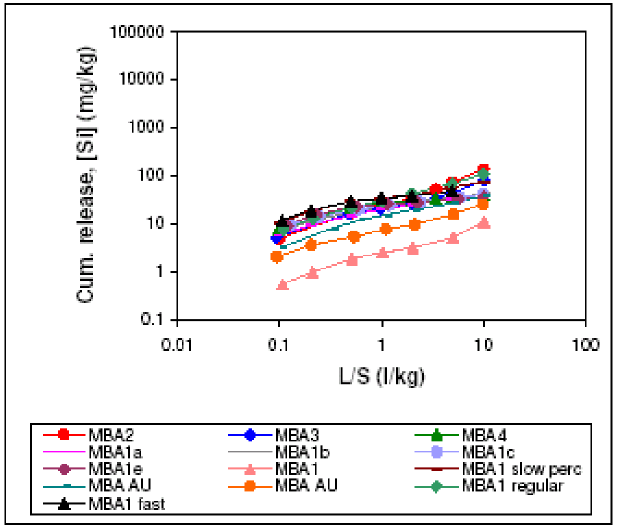

pH
Time (days)
[Si] (µg/l)
[S] (µg/l)
[Zn] (µg/l)

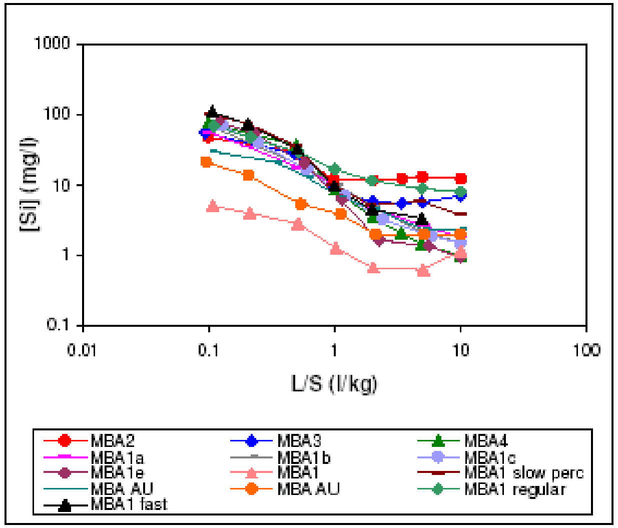


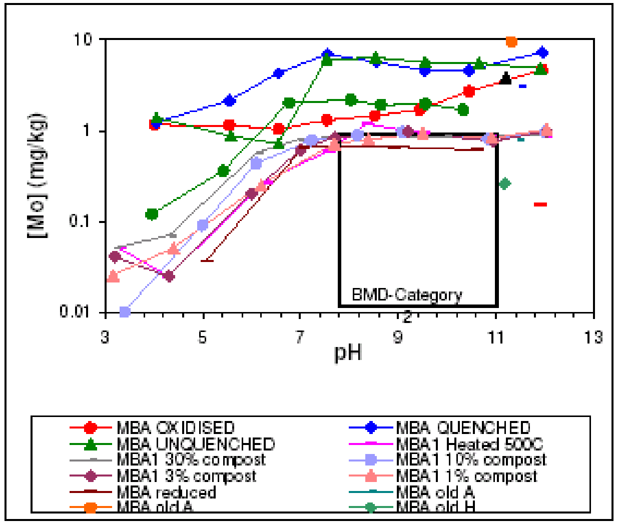

pH
Time (days)
Cum. release, [Cd] (mg/m²)
Cum. release, [Pb] (mg/m²)
[Pb] (µg/l)
[Mo] (µg/l)
[Cd] (µg/l)

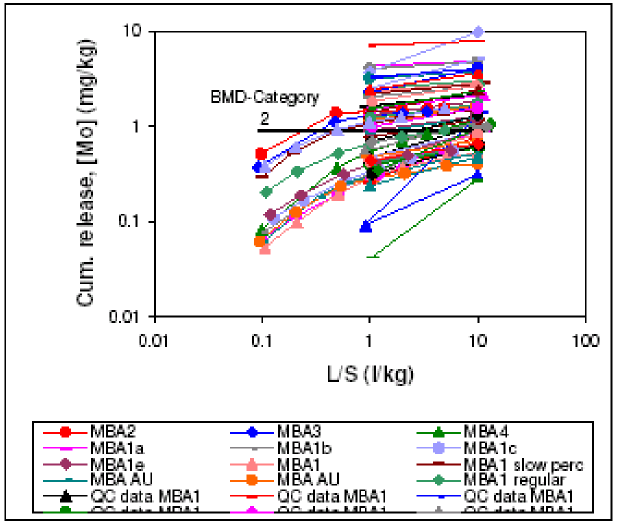
Appendix C QC CHAR MBA

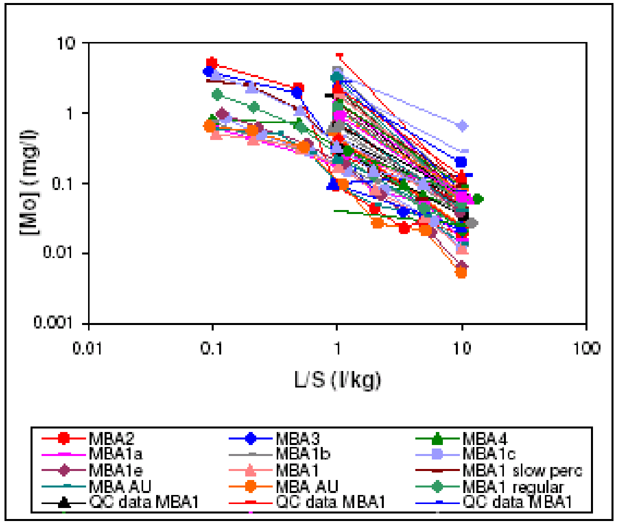


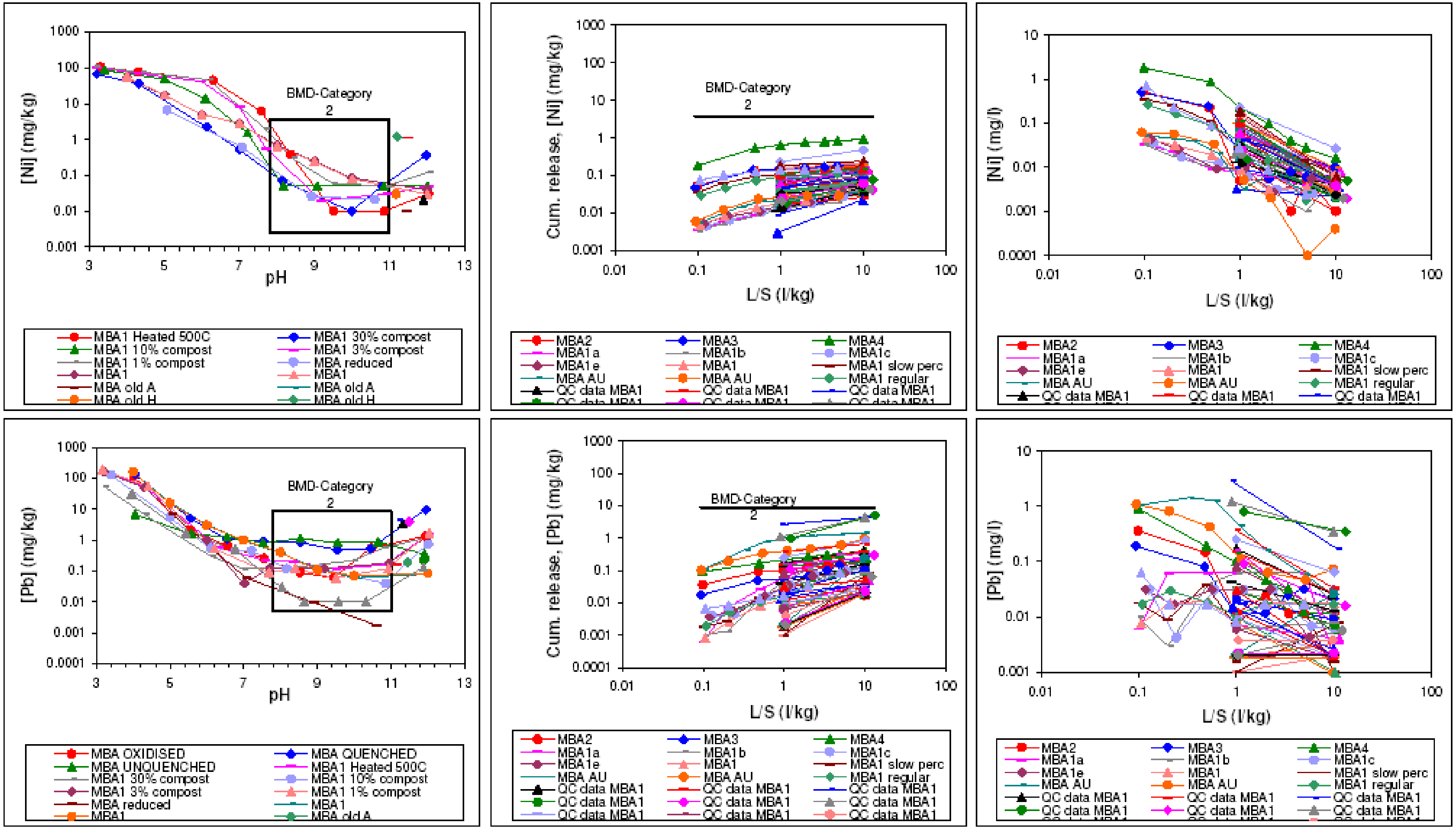


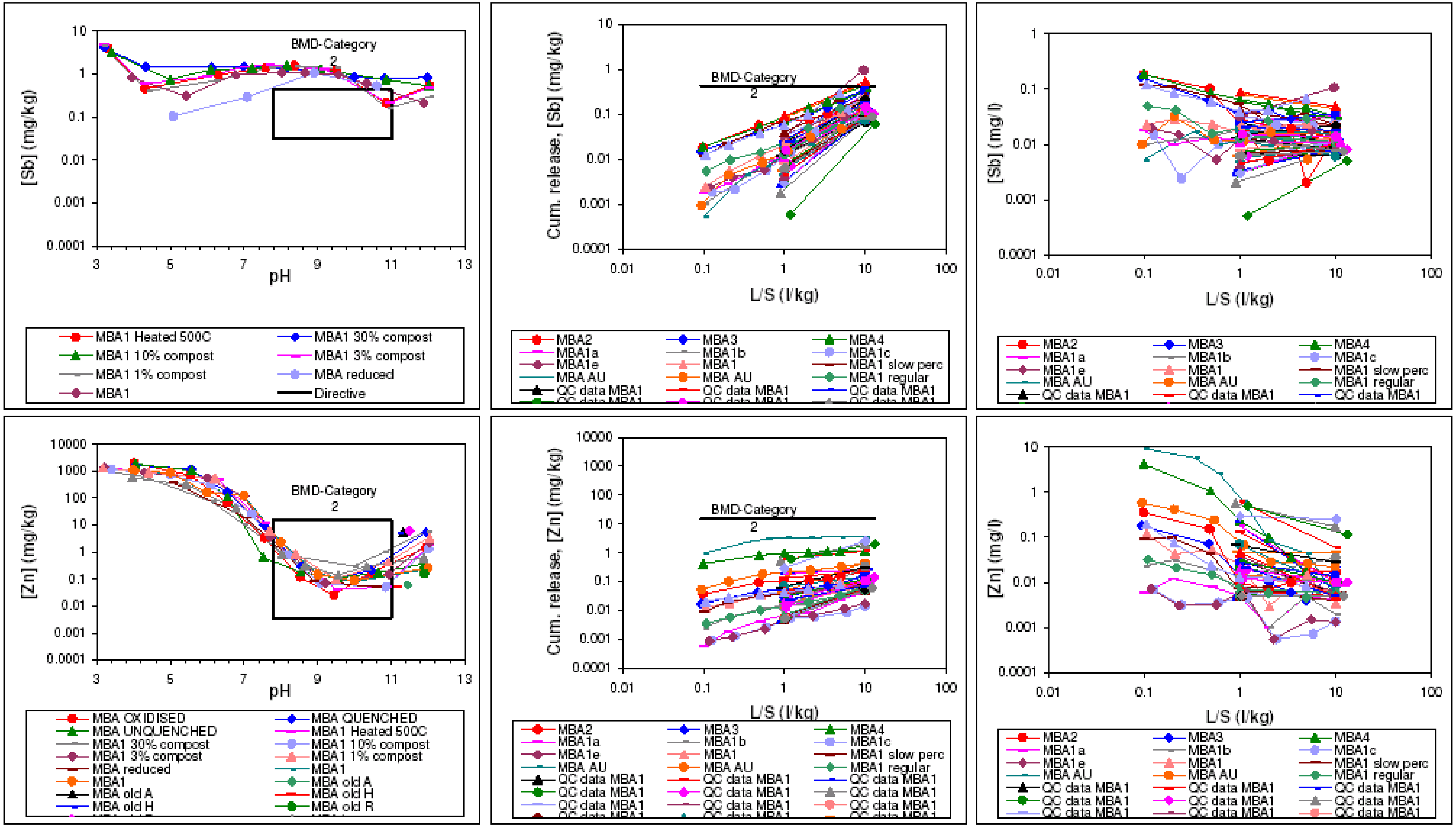




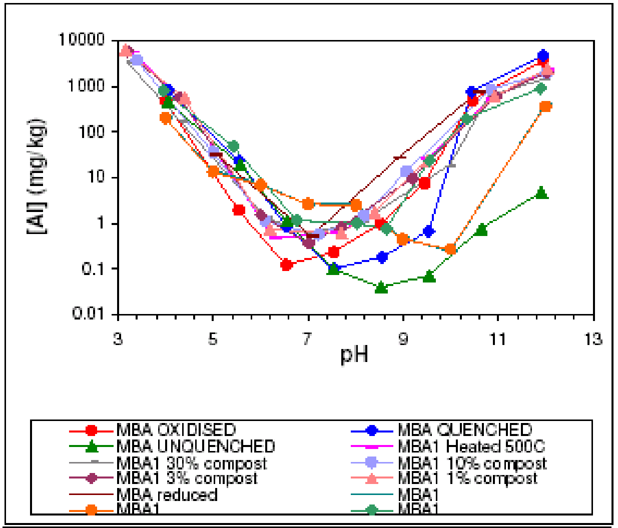


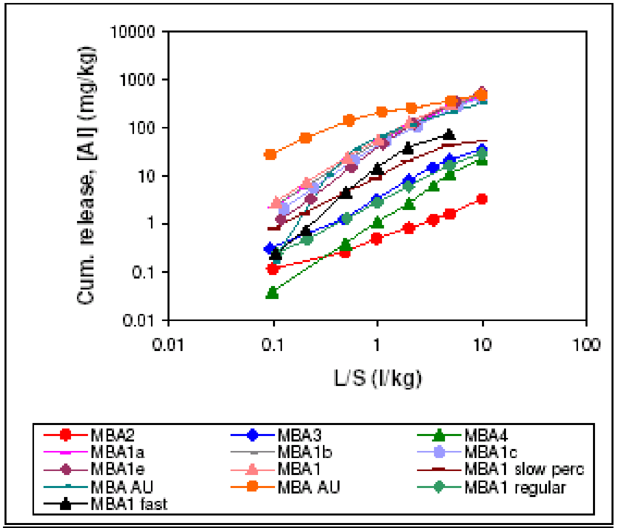


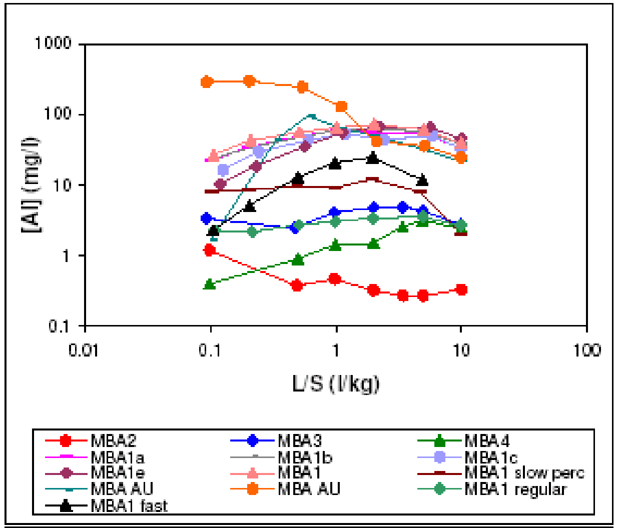

[Ni] (mg/kg)
pH
BMD-Category 2
MBA1 Heated 500C
MBA1 30% compost
MBA1 10% compost
MBA1 3% compost
MBA1 1% compost
MBA reduced
MBA1
MBA old A
MBA old H
Cum. release, [Ni] (mg/kg)
L/S (l/kg)
[Ni] (mg/l)
MBA2
MBA3
MBA4
MBA1a
MBA1b
MBA1c
MBA1e
MBA1 slow perc
MBA AU
MBA1 regular
QC data MBA1
[Pb] (mg/kg)
MBA OXIDISED
MBA QUENCHED
MBA UNQUENCHED
Cum. release, [Pb] (mg/kg)
[Pb] (mg/l)

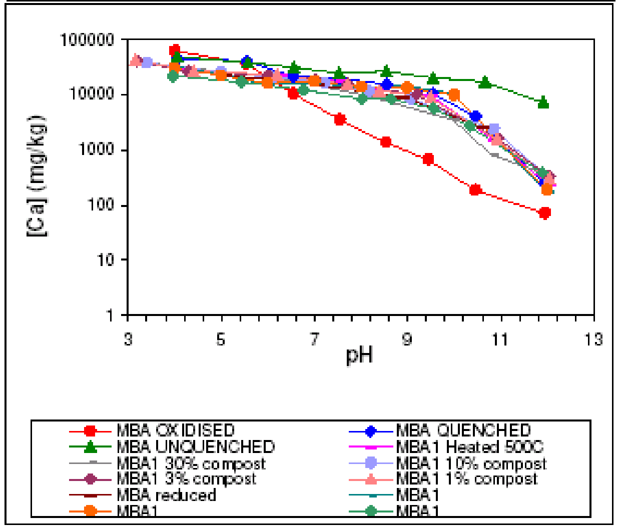


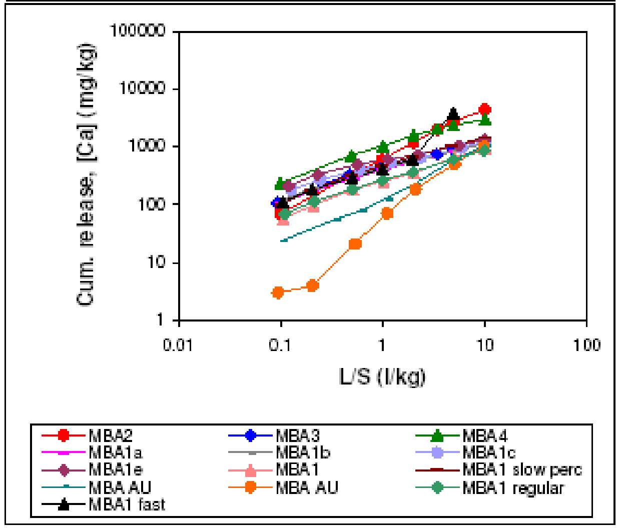
[Sb] (mg/kg)
pH
BMD-Category 2
MBA1 Heated 500C
MBA1 30% compost
MBA1 10% compost
MBA1 3% compost
MBA1 1% compost
MBA reduced
MBA1
Directive
Cum. release, [Sb] (mg/kg)
L/S (l/kg)
BMD-Category 2
MBA2
MBA3
MBA4
MBA1a
MBA1b
MBA1c
MBA1e
MBA1
MBA1 slow perc
MBA AU
MBA AU
MBA1 regular
QC data MBA1
QC data MBA1
QC data MBA1
[Sb] (mg/l)
L/S (l/kg)
[Zn] (mg/kg)
pH
BMD-Category 2
MBA OXIDISED
MBA QUENCHED
MBA UNQUENCHED
MBA1 Heated 500C
MBA1 30% compost
MBA1 10% compost
MBA1 3% compost
MBA1 1% compost
MBA reduced
MBA1
MBA1
MBA old A
MBA old A
MBA old H
MBA old H
MBA old R
Cum. release, [Zn] (mg/kg)
L/S (l/kg)
BMD-Category 2
QC data MBA1
[Zn] (mg/l)
L/S (l/kg)

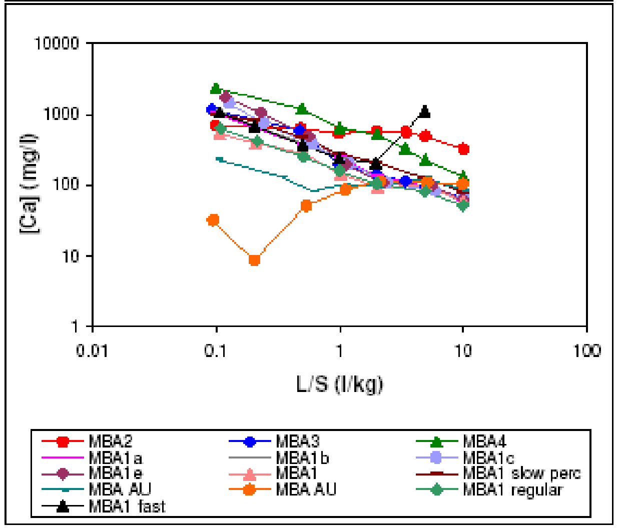

[Al] (mg/kg)
10000
1000
100
10
1
0.1
0.01
3
5
7
9
11
13
pH
MBA OXIDISED
MBA QUENCHED
MBA UNQUENCHED
MBA1 Heated 500C
MBA1 30% compost
MBA1 10% compost
MBA1 3% compost
MBA1 1% compost
MBA reduced
MBA1
MBA1
MBA1

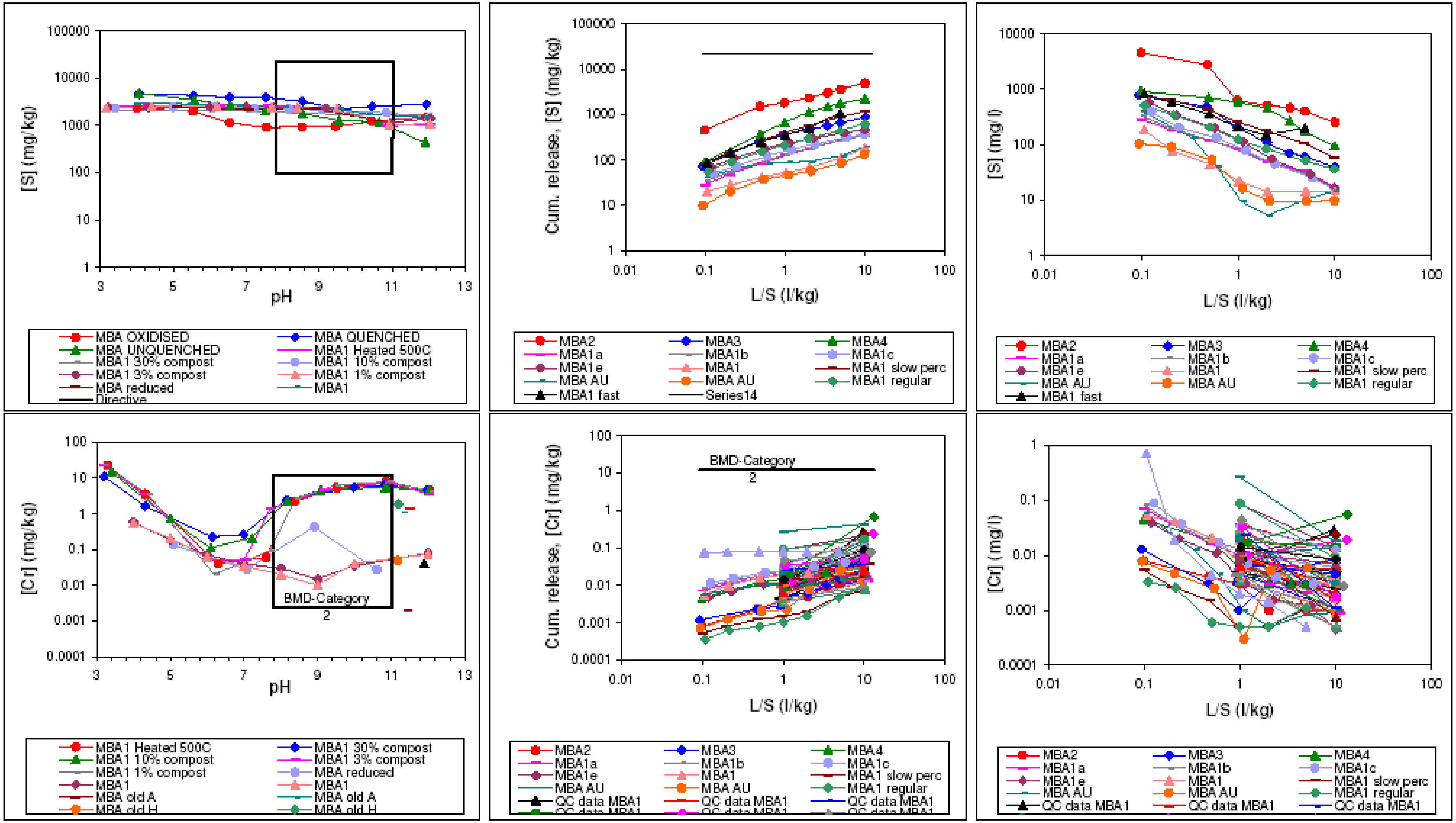

Cum. release, [Al] (mg/kg)
10000
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
L/S (l/kg)
MBA2
MBA3
MBA4
MBA1a
MBA1b
MBA1c
MBA1e
MBA1
MBA1 slow perc
MBA AU
MBA AU
MBA1 regular
MBA1 fast

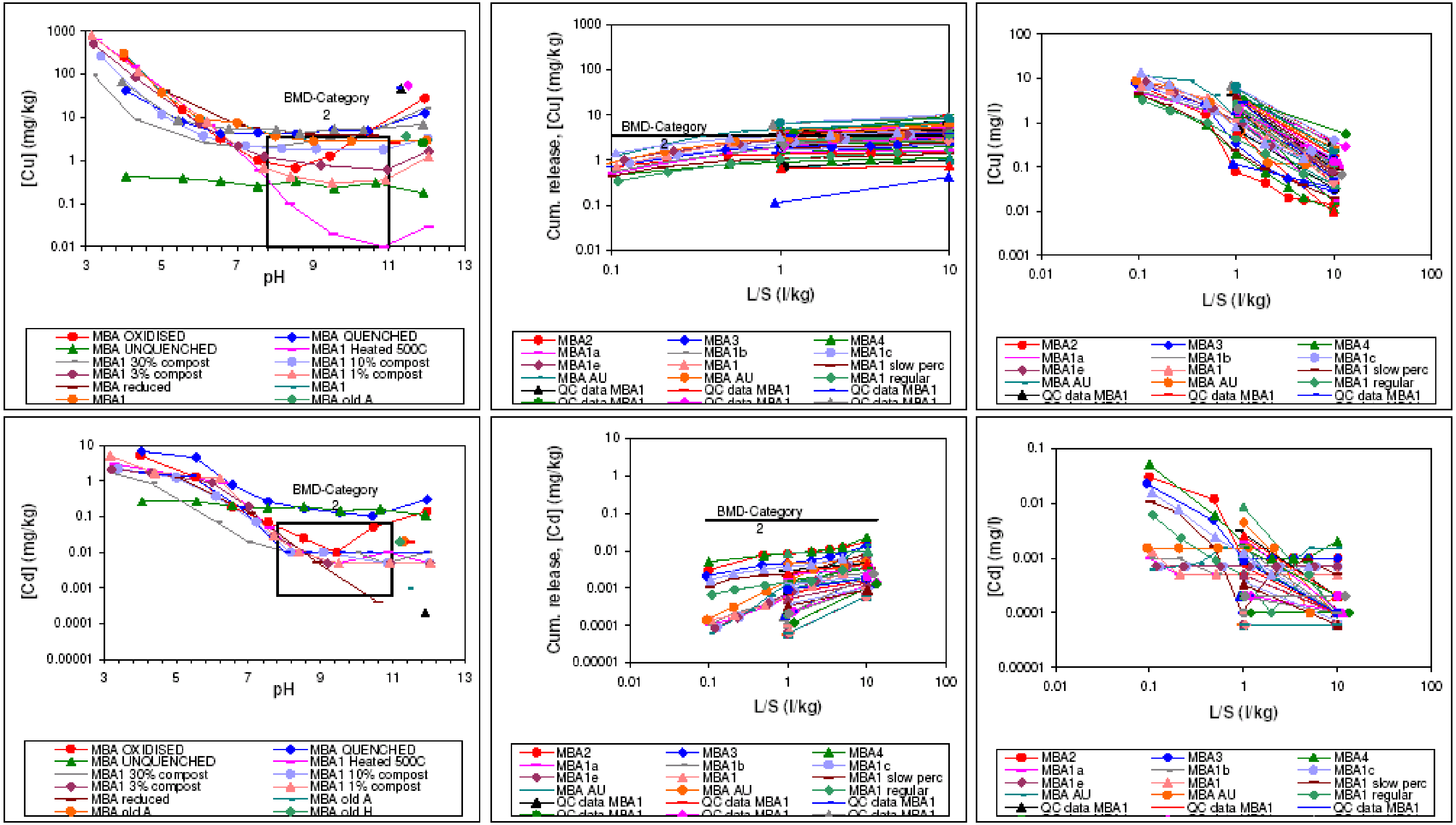

[Al] (mg/l)
1000
100
10
1
0.1
0.01
0.1
1
10
100
L/S (l/kg)
MBA2
MBA3
MBA4
MBA1a
MBA1b
MBA1c
MBA1e
MBA1
MBA1 slow perc
MBA AU
MBA AU
MBA1 regular
MBA1 fast


[Ca] (mg/kg)
100000
10000
1000
100
10
1
3
5
7
9
11
13
pH
MBA OXIDISED
MBA QUENCHED
MBA UNQUENCHED
MBA1 Heated 500C
MBA1 30% compost
MBA1 10% compost
MBA1 3% compost
MBA1 1% compost
MBA reduced
MBA1
MBA1
MBA1


Cum. release, [Ca] (mg/kg)
100000
10000
1000
100
10
1
0.01
0.1
1
10
100
L/S (l/kg)
MBA2
MBA3
MBA4
MBA1a
MBA1b
MBA1c
MBA1e
MBA1
MBA1 slow perc
MBA AU
MBA AU
MBA1 regular
MBA1 fast


[Ca] (mg/l)
10000
1000
100
10
1
0.01
0.1
1
10
100
L/S (l/kg)
MBA2
MBA3
MBA4
MBA1a
MBA1b
MBA1c
MBA1e
MBA1
MBA1 slow perc
MBA AU
MBA AU
MBA1 regular
MBA1 fast


[S] (mg/kg)
pH
BMD-Category 2
MBA OXIDISED
MBA QUENCHED
MBA UNQUENCHED
MBA1 Heated 500C
MBA1 30% compost
MBA1 10% compost
MBA1 3% compost
MBA1 1% compost
MBA reduced
MBA1
Directive
Cum. release, [S] (mg/kg)
L/S (l/kg)
MBA2
MBA3
MBA4
MBA1a
MBA1b
MBA1c
MBA1e
MBA1
MBA1 slow perc
MBA AU
MBA AU
MBA1 regular
MBA1 fast
Series14
[S] (mg/l)
[Cr] (mg/kg)
MBA1 Heated 500C
MBA1 30% compost
MBA1 10% compost
MBA1 3% compost
MBA1 1% compost
MBA reduced
MBA1
MBA1
MBA old A
MBA old A
MBA old H
MBA old H
Cum. release, [Cr] (mg/kg)
QC data MBA1
[Cr] (mg/l)

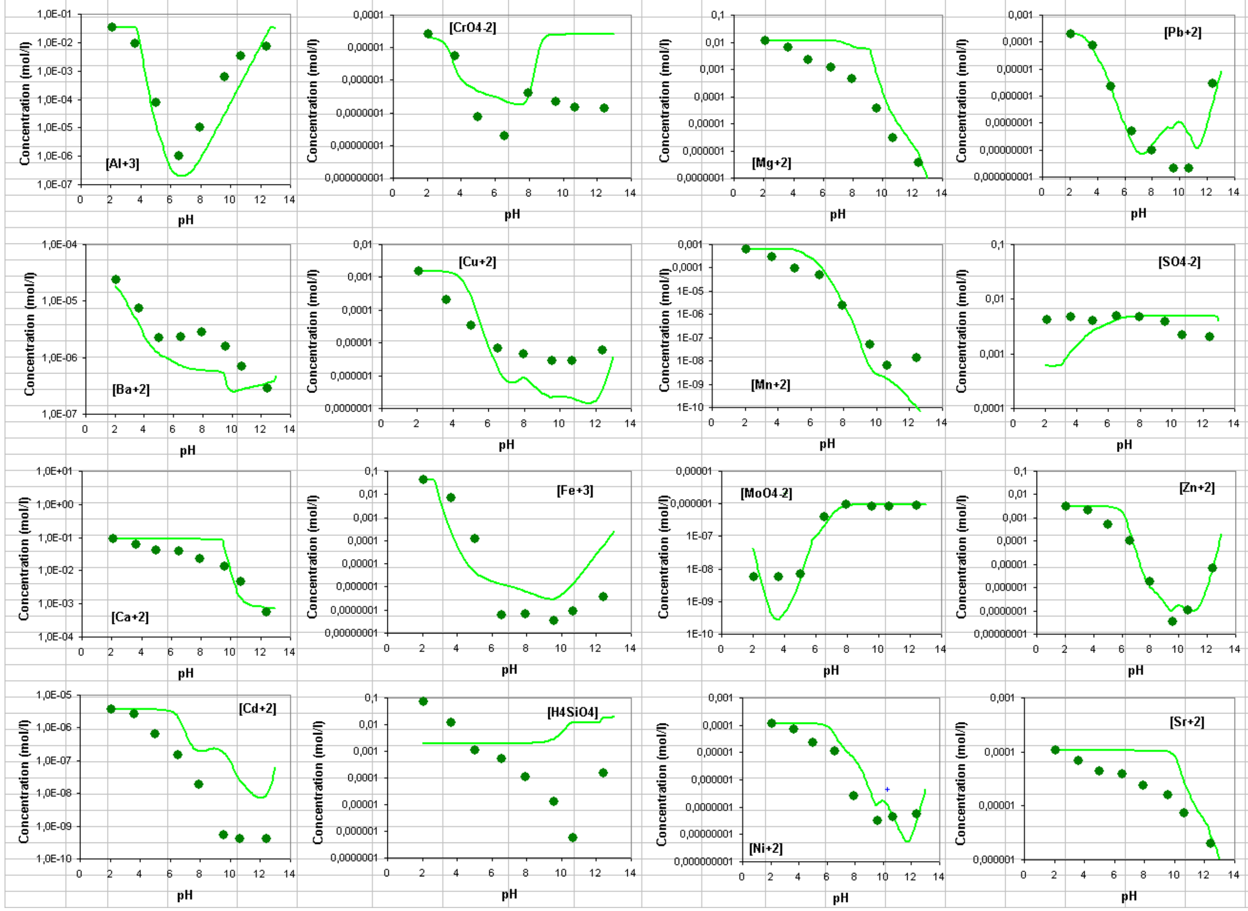

[Cu] (mg/kg)
pH
BMD-Category 2
MBA OXIDISED
MBA QUENCHED
MBA UNQUENCHED
MBA1 Heated 500C
MBA1 30% compost
MBA1 10% compost
MBA1 3% compost
MBA1 1% compost
MBA reduced
MBA1
MBA old A
Cum. release, [Cu] (mg/kg)
L/S (l/kg)
MBA2
MBA3
MBA4
MBA1a
MBA1b
MBA1c
MBA1e
MBA1 slow perc
MBA AU
MBA1 regular
QC data MBA1
[Cu] (mg/l)
[Cd] (mg/kg)
MBA old H
Cum. release, [Cd] (mg/kg)
[Cd] (mg/l)

Appendix D Speciation

D.1 MSWI bottom ash

GEOCHEMICAL MODELLING OF CEMENT MATRIX USING ON SET OF CONDITIONS
FOR ALL MAJOR,MINOR AND TRANC E ELEMENTS
Input for model are element availabilities (25) and relevant mineral phases (see below)

GEOCHEMICAL MODELLING OF CEMENT MATRIX USING ON SET OF CONDITIONS
FOR ALL MAJOR,MINOR AND TRANC E ELEMENTS
Input for model are element availabilities (25) and relevant mineral phases (see below)



MSWI Bottom ash

pH dependence leaching test data according to TS14429
(not a validated method yet due to lack of funds for validation)

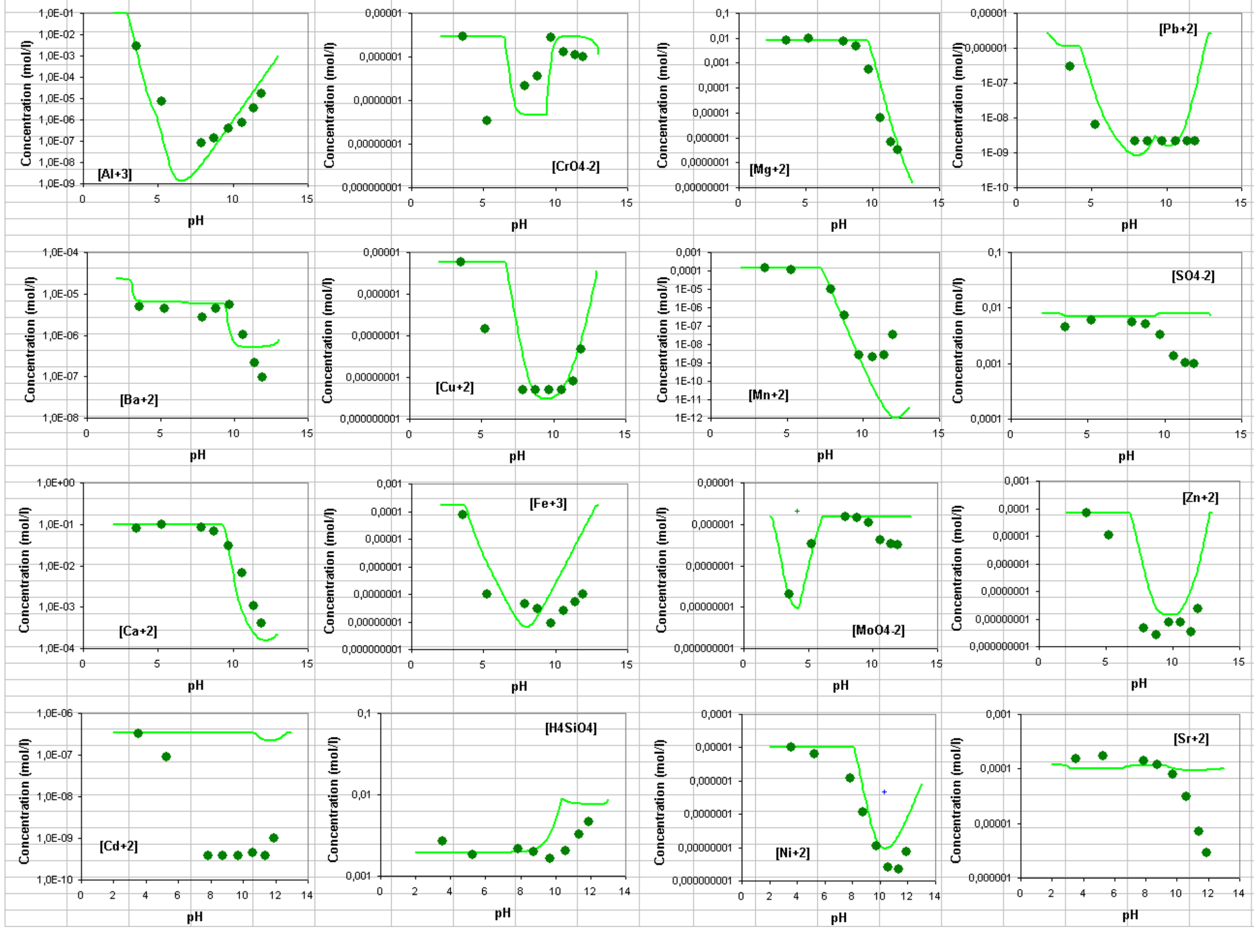
LS	DOC parameters a	b	c	d	Sorption parameters CLAY_kgkg	HFO_kgkg	SHA_kgkg
10	1,00E-05	-2,00E-06	1,95E-07	-6,00E-09	0,00E+00	7,57E-02	6,48E-04

Minerals		Element	Availability mg/kg
(Anhydrite)			
(Barite)	Al+3		8907,4042
(BaSrSO4[50%Ba])	H3AsO4	as As	0,048
(Brucite)	H3BO3	as B	51,01
(Cd[OH]2[C])	Ba+2		32,554098
(Cr-Ettringite)	Ca+2		36821,597
(CSH_ECN)	Cd+2		4,0608026
(Cu[OH]2[s])	Co+2		3,6
(Ettringite_ECN)	CrO4-2	as Cr	13,29964
(Fe2[MoO4]3[1])	Cu+2		988,1905
(Ferrihydrite)	Fe+3		22741,937
(Forsterite)	K+		1296,02
(Gibbsite[C])	Li+		50,2
(Manganite)	Mg+2		2796,6039
(MnHPO4[C])	Mn+2		342,73639
(monosulfate_ECN)	MoO4-2	as Mo	0,89455
(Ni[OH]2[s])	Na+		1700,1
(Ni2SiO4)	Ni+2		66,322858
(Pb[OH]2[C])	PO4-3	as P	216,1
(Pb2V2O7)	Pb+2		409,3644
(PbCrO4)	SO4-2	as S	1559,8286
(PbMoO4[c])	Sb[OH]6-	as Sb	4,3389069
(Sb[OH]3[s])	H4SiO4	as Si	30304,711
(SiO2[am])	Sr+2		92,56
(Tenorite)	VO2+	as V	4,7244464
(Willemite)	Zn+2		1982,6015
(Zn[OH]2[E])	Cl-		2796,1
	H2CO3	as C	5050,1

D.2 Cement mortar

GEOCHEMICAL MODELLING OF CEMENT MATRIX USING ON SET OF CONDITIONS
FOR ALL MAJOR,MINOR AND TRANC E ELEMENTS
Input for model are element availabilities (25) and relevant mineral phases (see below)

GEOCHEMICAL MODELLING OF CEMENT MATRIX USING ON SET OF CONDITIONS
FOR ALL MAJOR,MINOR AND TRANC E ELEMENTS
Input for model are element availabilities (25) and relevant mineral phases (see below)



Cement mortar

pH dependence leaching test data according to TS14429
(not a validated method yet due to lack of funds for validation)

Key missing information:
anion substitution data in ettringite type phases. (V, Mo, Sb, As, Se, B,)

Minerals		Element	Available (mg/kg)
(Analcime)			
(Anhydrite)			
(Ba[SCr]O4[77%SO4])	Al+3		25739,81
(BaSrSO4[50%Ba])	H3AsO4	as As	1,380893
(Boehmite)	H3BO3	as B	123,6375
(Brucite)	Ba+2		63,79171
(CaMoO4[c])	Ca+2		40378,24
(Cd[OH]2[C])	Cd+2		0,378117
(Cr[OH]3[C])	Co+2		2,459858
(Cr-Ettringite)	CrO4-2	as Cr	12,73323
(CSH_ECN)	Cu+2		3,753115
(Diaspore)	Fe+3		96,40153
(Ettringite_ECN)	K+		992,5576
(Ferrihydrite)	Li+		4,362208
(Gibbsite[C])	Mg+2		2057,217
(Manganite)	Mn+2		77,42697
(MnHPO4[C])	MoO4-2	as Mo	1,448633
(Ni[OH]2[s])	Na+		370,1602
(Pb[OH]2[C])	Ni+2		6,048115
(Pb2V2O7)	PO4-3	as P	1,24956
(Pb3[VO4]2)	Pb+2		5,413154
(PbCrO4)	SO4-2	as S	2558,219
(PbMoO4[c])	Sb[OH]6-	as Sb	0,072037
(Portlandite)	H4SiO4	as Si	30415,82
(SiO2[am])	Sr+2		123,5226
(Tenorite)	VO2+	as V	5,44512
(Willemite)	Zn+2		45,67481

Appendix E Test Methods

pH DEPENDENCE TEST TO ASSESS SENSITIVITY TO CHANGES IN pH, EH AND TEMPERATURE

(PrTS14429 Batch pH dependence test and PrEN 14997 computer controlled version)

Advantages:

- Identification of sensitivity of leaching to small pH changes
- Provides information on pH conditions imposed by external influences
- Basis for comparison of international leaching tests
- Basis for geochemical speciation modelling
- Provides acid neutralization capacity information
- Mutual comparison of widely different materials to assess similarities in leaching behaviour
- Recognition of factors controlling release
- For non-interacting species possible to assess sub-sampling error
- Applicable to a wide range of materials

PERCOLATION TEST TO ASSESS LONG TERM RELEASE FOR GRANULAR MATERIALS PrEn14405

Liquid to solid ratio (L/S) related to a time scale by infiltration rate, density and height of application.

TEST CONDITIONS:
Pre-equilibration after saturation for more than 48 hrs
Up-flow
L/S range 0.1 - 10 (100 - 1000 yrs)
Test data in mg/l or mg/kg cumulative

Advantages:

- Identification of solubility control versus wash out
- Indication of pore water concentrations relevant to field leachate from low L/S data
- Local equilibrium established quite rapidly
- Basis for geochemical speciation modelling
- Allows comparison with lysimeter and field data provided L/S value can be obtained from such measurements
- Projection towards long term behaviour possible
  - Solubility controlled release
  - Wash-out of non-interacting species
- \- Applicable to many materials

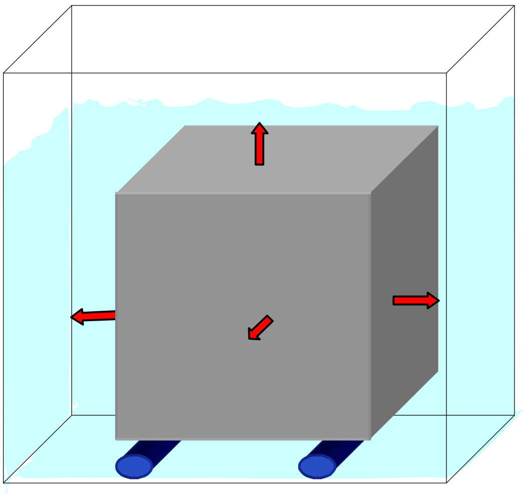
Disadvantages:

- Limited or not applicable to clayey soils
- Sediments (low permeability).

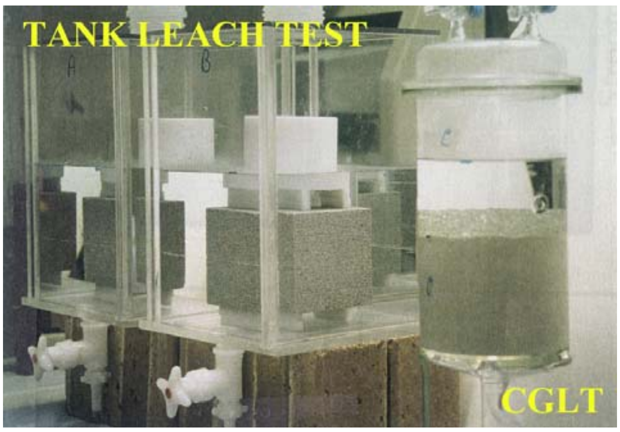
TANK LEACH TEST OR COMPACTED GRANULAR LEACH TEST (CGLT) FOR MONOLITHIC MATERIALS (modified)

TEST CONDITIONS:
First step: pre-equilibration
for 48 hrs at liquid to
volume ratio: 5
Second step: leaching
at low L/V ratio (1) for 24 hrs
Then contact times: 2, 4, 8,16, 32 and 64 days
Leachant: demineralised water (own pH)

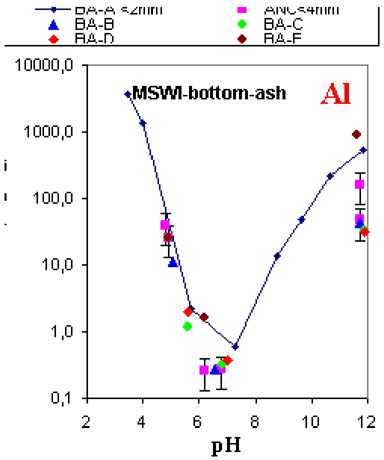
Expression of results in mg/m^2 (cumulative) against time
CGLT = Compacted Granular Leach Test

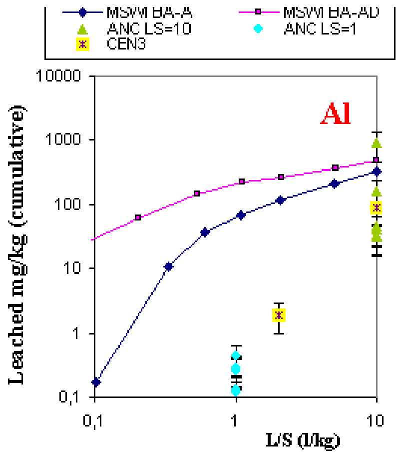


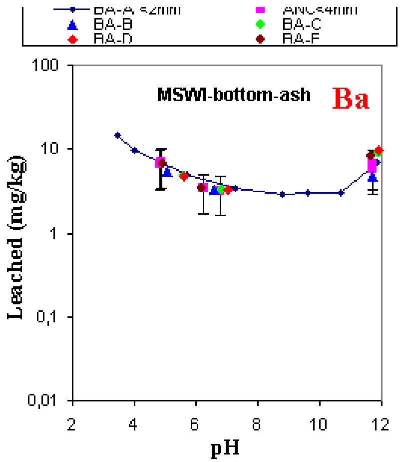
Advantages:
- Relevant for materials with monolithic character (durable materials) or materials behaving as monolith (low permeability soil and sediments)
- Identification of solubility control versus dynamic leaching possible
- Isolation of surface wash-off effects
- Quantification of intrinsic release parameters
- Basis for reactive/transport modelling
- Projection towards long term behaviour possible
- Applicable to sediments, clayey soils, stabilised materials and construction materials produced

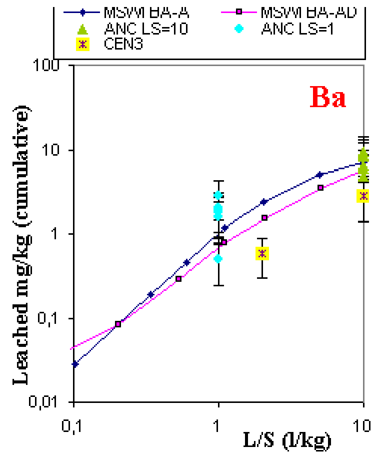


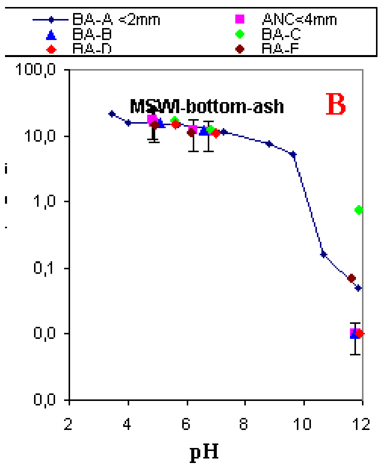
Appendix F MSWI BA AU

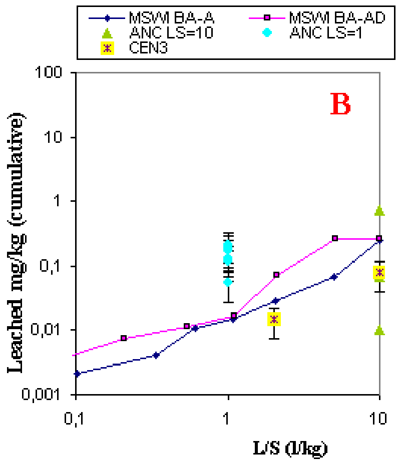


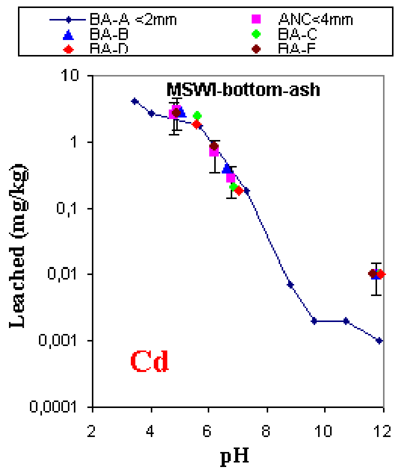


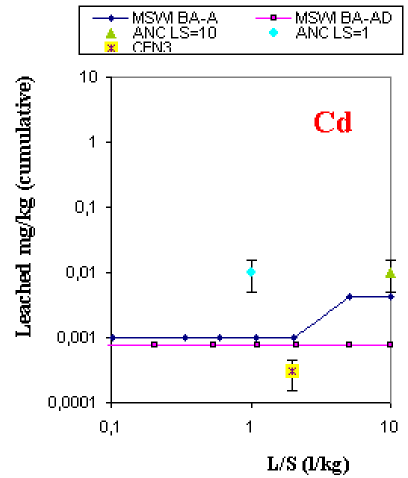


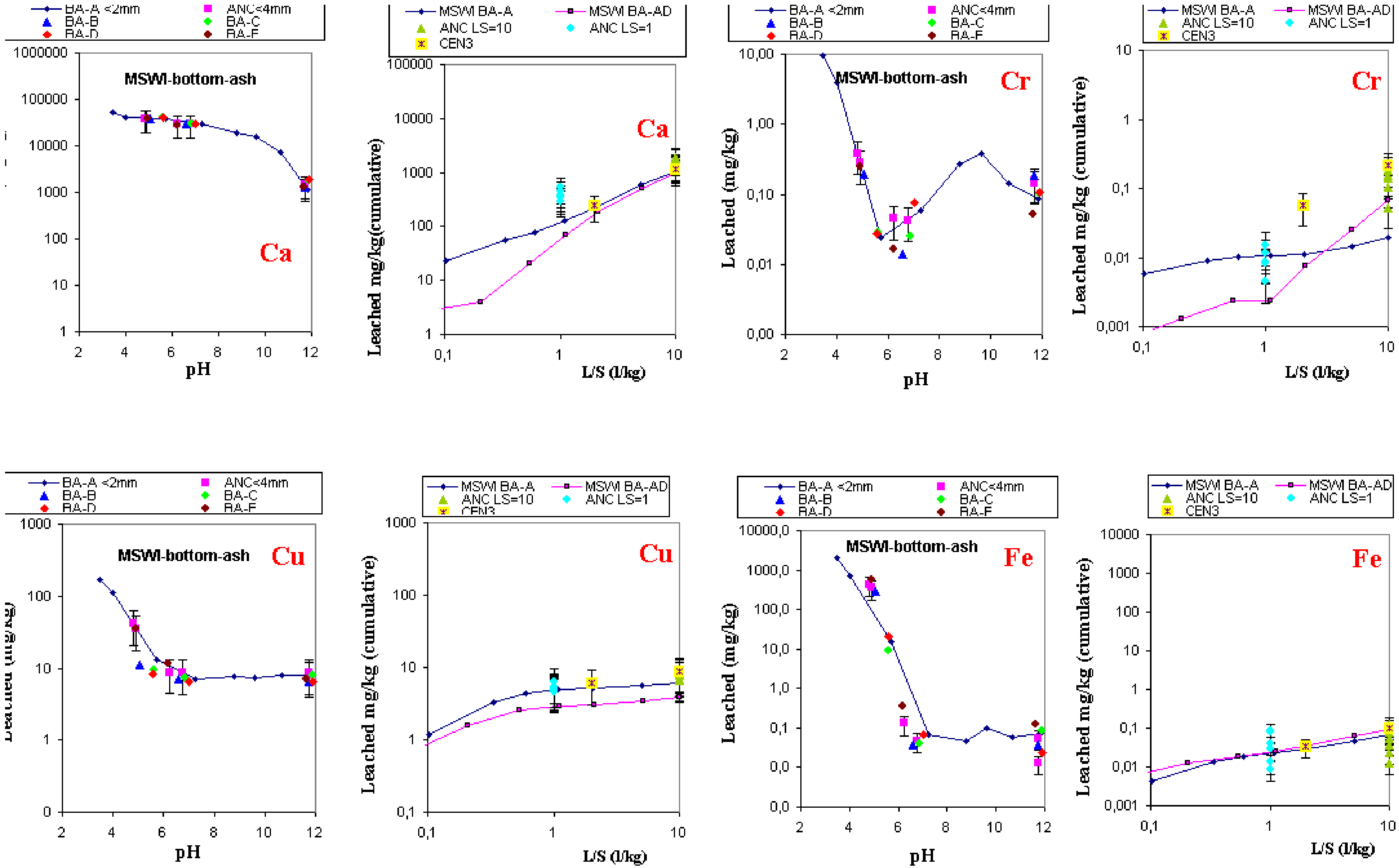


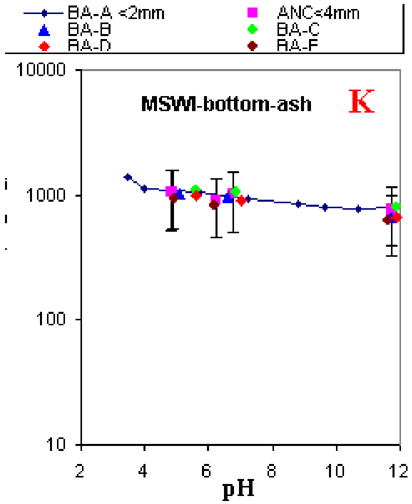









BA-A <2mm
ANC<4mm
BA-B
BA-C
BA-D
BA-F
MSWI-bottom-ash
Ca
pH
MSWI BA-A
MSWI BA-AD
ANC LS=10
ANC LS=1
CEN3
Leached mg/kg(cumulative)
L/S (l/kg)
Cr
Leached (mg/kg)
Leached mg/kg (cumulative)
Cu
Fe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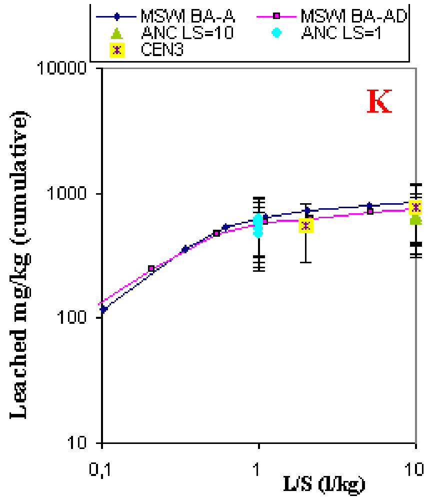
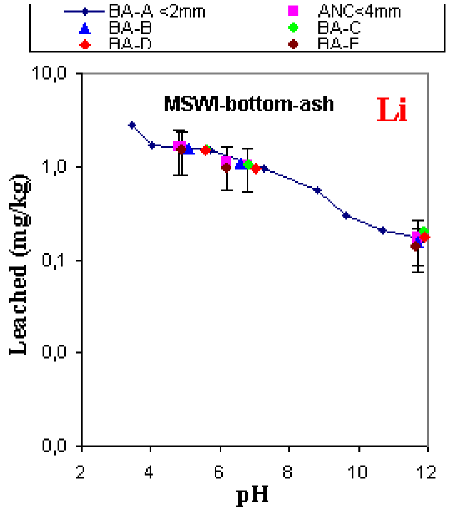
BA-B
BA-D
ANC<4mm
BA-C
BA-F
MSWI-bottom-ash
K
pH


MSWI BA-A
ANC LS=10
CEN3
MSWI BA-AD
ANC LS=1
K
Leached mg/kg (cumulative)
L/S (l/kg)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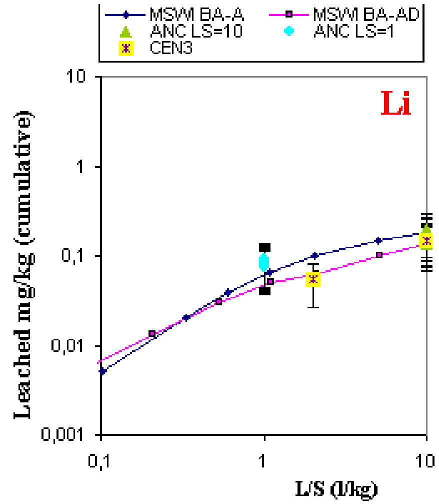
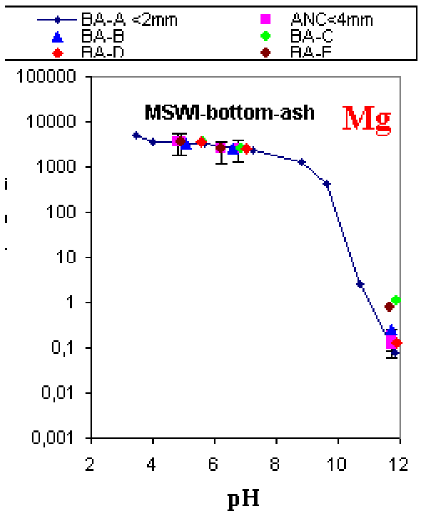
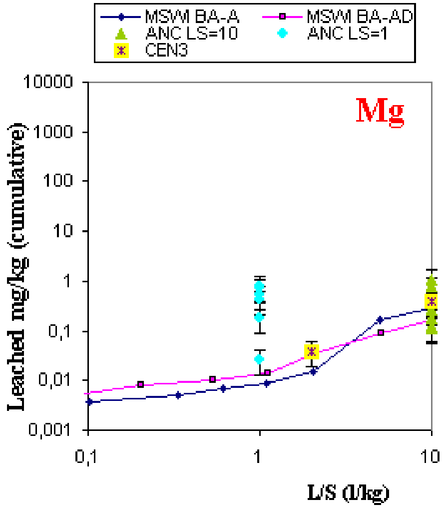
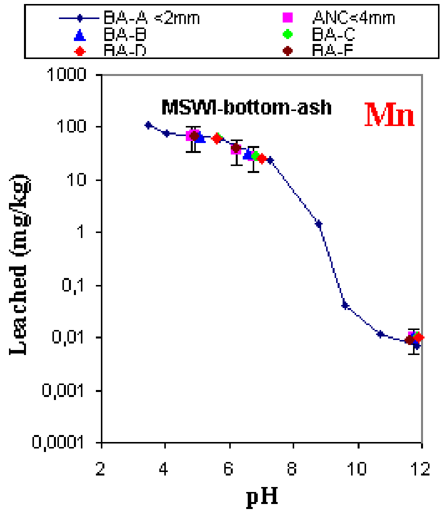
BA-B
BA-D
ANC<4mm
BA-C
BA-F
MSWI-bottom-ash
Li
Leached (mg/kg)
pH


MSWI BA-A
ANC LS=10
CEN3
MSWI BA-AD
ANC LS=1
Li
Leached mg/kg (cumulative)
L/S (l/kg)


BA-A <2mm
BA-B
BA-D
ANC<4mm
BA-C
BA-F
MSWI-bottom-ash
Mg
pH


MSWI BA-A
ANC LS=10
CEN3
MSWI BA-AD
ANC LS=1
Mg
Leached mg/kg (cumulative)
L/S (l/kg)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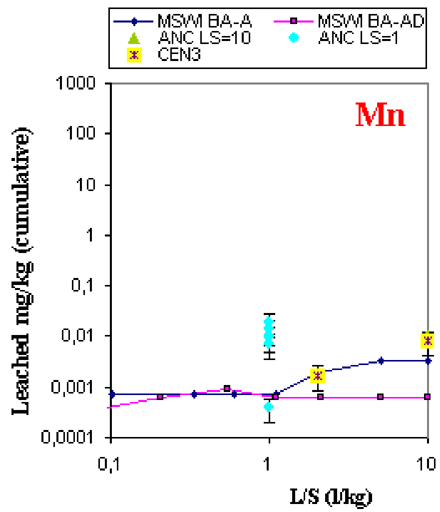
BA-B
BA-D
ANC<4mm
BA-C
BA-F
MSWI-bottom-ash
Mn
Leached (mg/kg)
pH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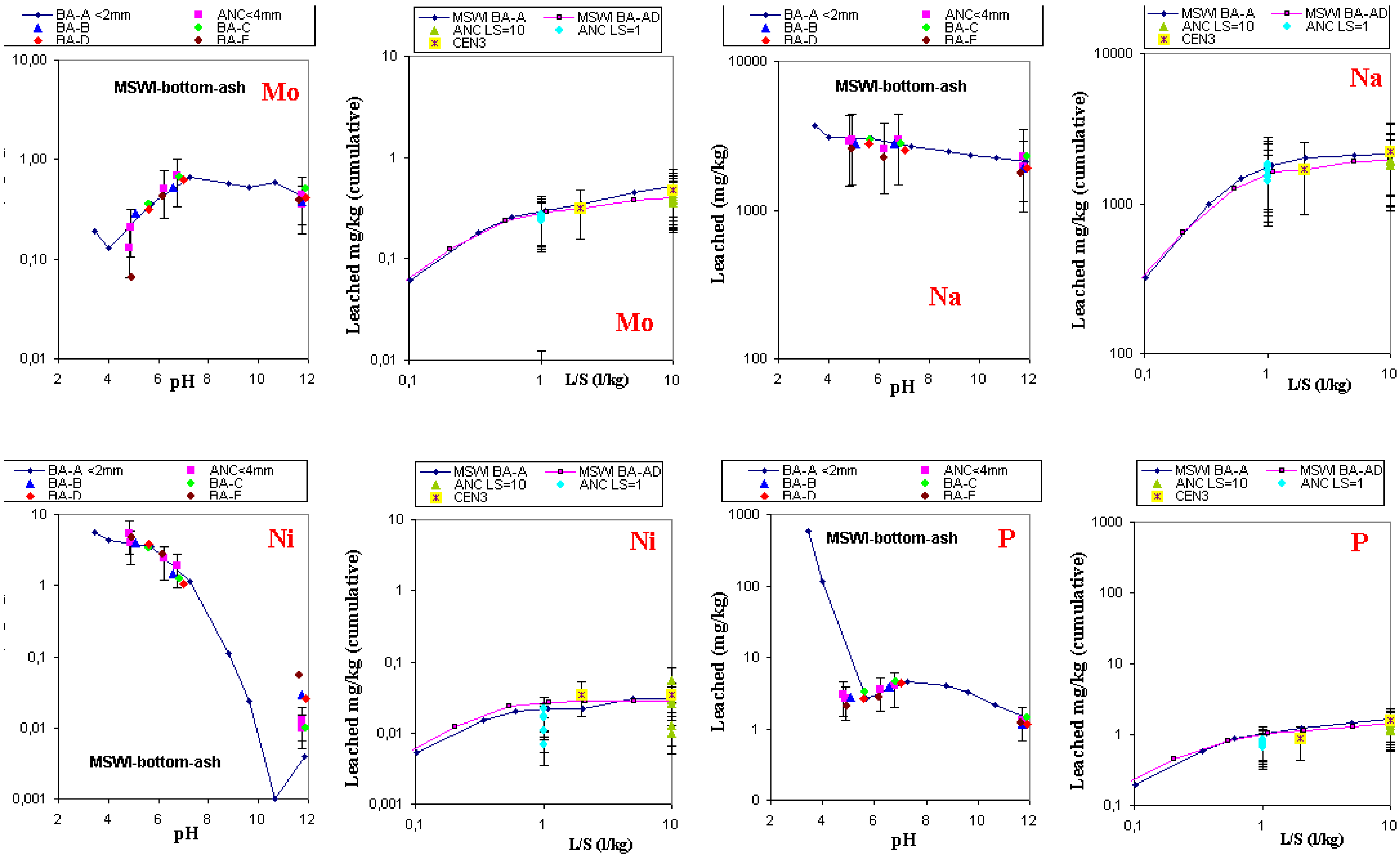
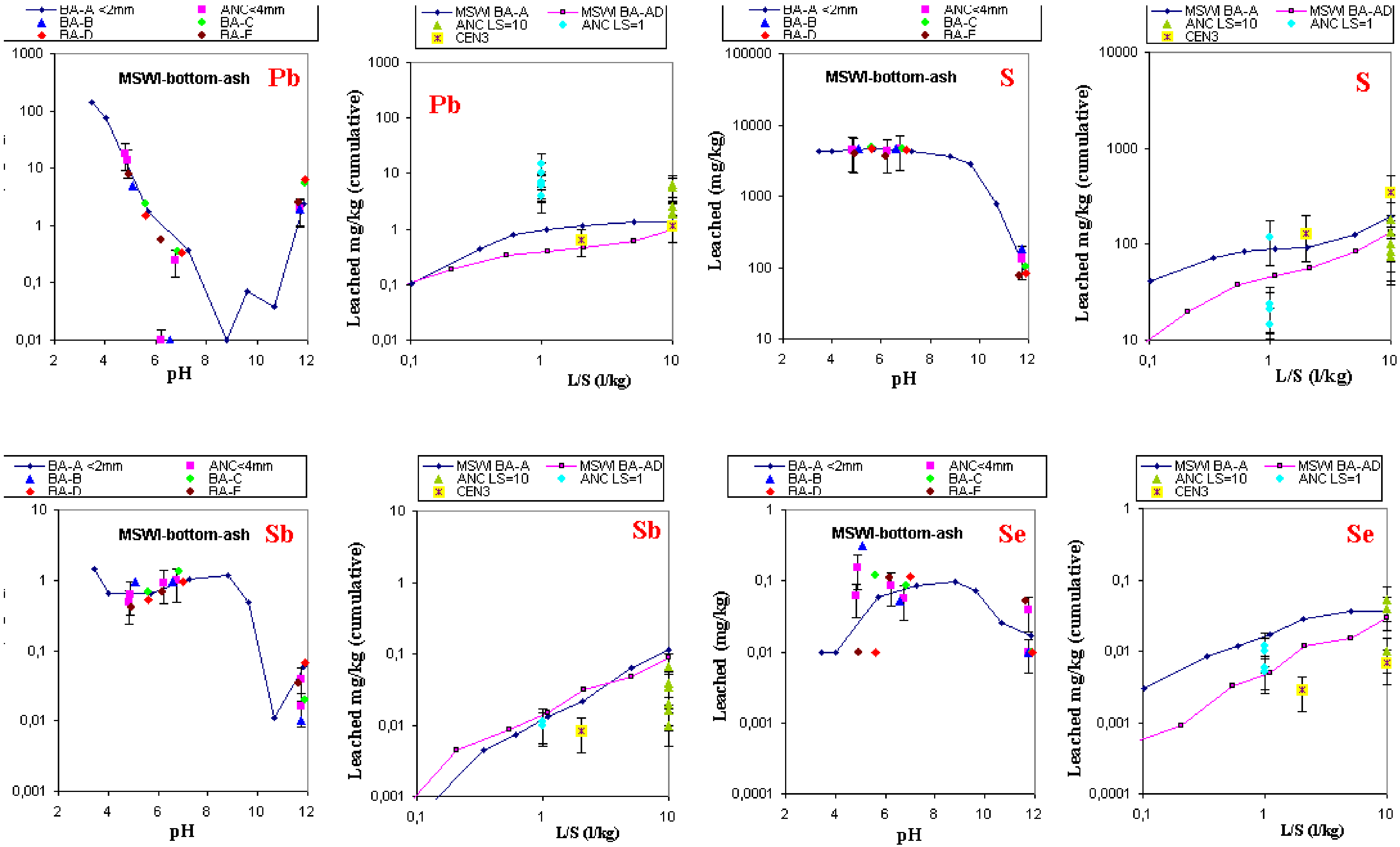
ANC LS=10
CEN3
MSWI BA-AD
ANC LS=1
Mn
Leached mg/kg (cumulative)
L/S (l/kg)


BA-A <2mm
BA-B
BA-D
ANC<4mm
BA-C
BA-F
MSWI-bottom-ash
Mo
pH
MSWI BA-A
MSWI BA-AD
ANC LS=10
ANC LS=1
CEN3
Leached mg/kg (cumulative)
L/S (l/kg)
Na
Leached (mg/kg)
Ni
P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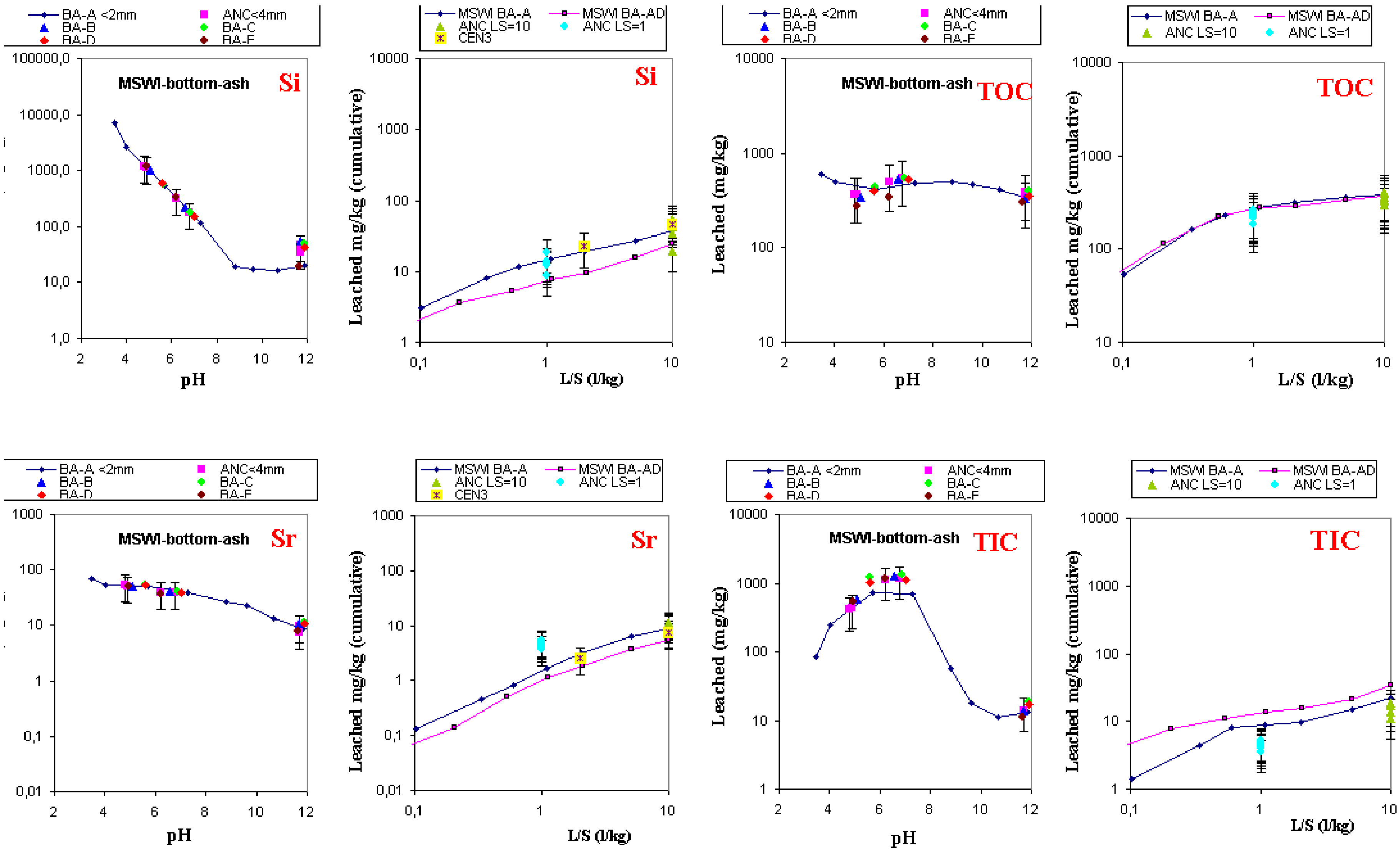
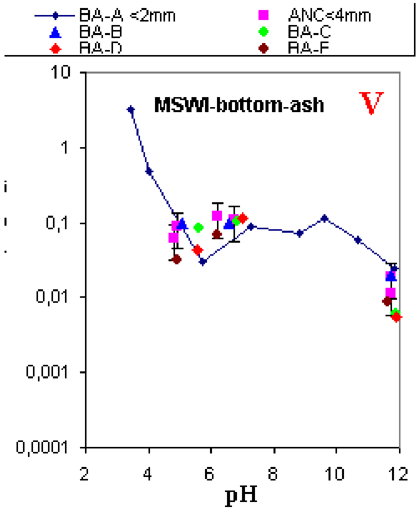
BA-B
BA-D
ANC<4mm
BA-C
BA-F
MSWI-bottom-ash
Pb
pH
MSWI BA-A
MSWI BA-AD
ANC LS=10
ANC LS=1
CEN3
Pb
Leached mg/kg (cumulative)
L/S (l/kg)
MSWI-bottom-ash
S
Leached (mg/kg)
pH
S
Leached mg/kg (cumulative)
L/S (l/kg)
MSWI-bottom-ash
Sb
pH
Sb
Leached mg/kg (cumulative)
L/S (l/kg)
MSWI-bottom-ash
Se
Leached (mg/kg)
pH
Se
Leached mg/kg (cumulative)
L/S (l/kg)


BA-A <2mm
BA-B
BA-D
ANC<4mm
BA-C
BA-F
MSWI-bottom-ash
Si
pH
MSWI BA-A
MSWI BA-AD
ANC LS=10
ANC LS=1
CEN3
Leached mg/kg (cumulative)
L/S (l/kg)
TOC
Leached (mg/kg)
Sr
TIC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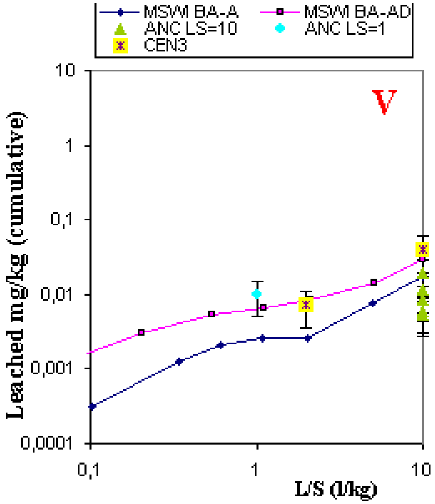
ANC<4mm
BA-B
BA-C
BA-D
BA-F
MSWI-bottom-ash
V
pH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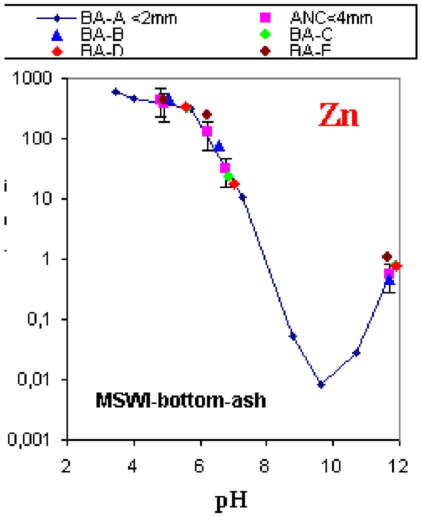
MSWI BA-AD
ANC LS=10
ANC LS=1
CEN3
V
Leached mg/kg (cumulative)
L/S (l/kg)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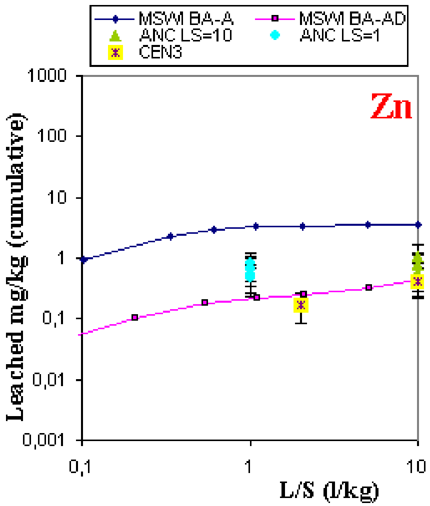
ANC<4mm
BA-B
BA-C
BA-D
BA-F
Zn
MSWI-bottom-ash
pH


MSWI BA-A
MSWI BA-AD
ANC LS=10
ANC LS=1
CEN3
Zn
Leached mg/kg (cumulative)
L/S (l/kg)