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A reference database in LeachXS™ Lite for release of substances from construction products including alternative materials.

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Abstract

The Construction Products Directive (CPD) will in 2013 be replaced by the Construction Products Regulation (CPR), which extends into recycling and end of life aspects. The development of appropriate standards has been taken up by CEN/TC 351, where a horizontal approach to testing is promoted to avoid multiplication of test protocols per sector. In parallel, IPTS-JRC is developing criteria for End of Waste (EoW). Redundant testing shall be avoided. Dossiers are being drafted to allow declaration of "without further testing" (WFT) for products as a whole, or for specific regulated substances potentially released from products. These dossiers call for information and test data on the wide variety of products covered by harmonised European standards. Experience has been gained with a range of products over the past decade. This information has been compiled in LeachXS™ Lite, which has been developed with support of US EPA for use in combination with the new EPA leaching test methods (same as CEN methods). In this abstract, recycled concrete, municipal solid waste incinerator bottom ash and basic oxygen steel slag are presented to be used by end users for comparison purposes. Additional benchmark cases are under development.

Keywords: Leaching, Benchmark, Concrete, Bottom ash, Steel slag, Database, Characterisation, Statistics.

1 Introduction

The environmental aspects of beneficial use of alternative materials in construction are high on the agenda in the EU. Current regulatory developments in the EU focus on fulfilling essential requirement 3 of The Construction Products Directive (CPD, 1989), which addresses health and environment aspects of service life of construction products. After the preparation of technical specifications covering the technical and physical aspects of use, the requirements with respect to environment and health needs to be addressed. The development of appropriate standards has been taken up by CEN/TC 351 (2010), where a horizontal approach to testing is promoted to avoid multiplication of test protocols per sector, which would lead to a substantial duplication of work. The robustness evaluation of two test methods relevant to impact to soil and groundwater is on-going and expected to be finalized by May 2012. The Construction Products Regulation (CPR) will replace the CPD by 2013 (2011). This regulation not only addresses service life, but extends to recycling and end of life aspects. The activities of IPTS-JRC (Delgado et al., 2009) in relation to the development of criteria for End of Waste (EoW) are closely related to these developments. The approaches and testing requirements shall ensure that redundant testing is avoided. In the framework of the CPD, dossiers are drafted to allow declaration of WFT for products as a whole, or for specific regulated substances released from products (CEN/TR 15858, 2010). These dossiers call for information and test data on the wide variety of products covered by the CPD. As regulations are in place in a few EU member states, experience has been gained with a range of products over the years. This information needs to be more readily

available to end-users. This is where LeachXS™ Lite (free), which has been developed with support of US EPA (Thorneloe et al, 2011), can play a role for use in combination with the new leaching test methods under validation now (Garrabrants et al, 2011) and prepared for incorporation in SW846 (book of EPA official test methods).

2 Materials and methods

For a wide range of materials, full characterisation data will become publicly available as part of the dossiers under development. Here information collected for municipal solid waste incinerator bottom ash (MSWI bottom ash), basic oxygen furnace (BOF) slag and recycled concrete are discussed. In the case of recycled concrete, SO_4^{-2}, Mg, As, Cd, Mo, Ni, V and Zn have been selected for illustration in this paper out of the full set of substances that are available. For BOF slag, SO_4^{-2}, V, Cu and Cr have been selected. For MSWI bottom ash, the elements Al, Cu, Mo and Zn are presented as illustration.

2.1 Leaching tests

For the proper characterisation of the release behaviour from municipal solid waste incinerator residues, construction wastes and construction products, a limited set of basic leaching tests addressing specific aspects of release behaviour are now in place. For the granular materials from the above list, the combination of the pH dependence test (CEN/TS14429, 2005; CEN/TS14997, 2005; ISO/TS21268-4, 207 and Draft US EPA Method 1313, 2009) and the percolation test (CEN/TS14405, 2004; ISO/TS21268-3, 2007; CEN/TC351 TS-3, 2009 and Draft US-EPA Method 1314, 2009) are the main tools. For monolithic products, the pH dependence test, percolation test (only first fractions to simulate pore water composition) and dynamic monolith leach test (CEN/TS15863, 2009; CEN/TC351 TS-2, 2009 and US EPA Draft Method 1315, 2009) are the relevant tools. In addition, the compacted granular leach test (embedded in CEN/TC351 TS-2 and US EPA Draft Method 1315) is a tool to address release from low permeability granular materials and non-porous coarse granular materials. A main advantage of standardised characterisation tests is that it allows benchmarks for materials to be established and avoids redundant testing for materials under different regulatory controls.

The pH dependence test addresses changes in exposure conditions and can be used to assess chemical speciation issues. The results of the pH dependence test are used in mechanistic geochemical speciation modelling to quantify the chemical phases (minerals and sorptive phases) controlling release. This information facilitates proper evaluation of long-term release behaviour from any of the above mentioned materials and products. The basic chemical speciation approach is the same for all materials, as in all cases mineral dissolution/precipitation, sorption on Fe, Al or Mn oxides, interaction with clay and interaction with dissolved (DOC) and particulate organic matter (POM) play a role. It is primarily the proportion in which specific release controlling phases contribute to the overall release behaviour that materials differ. Tools to quantify the relevant reactive surfaces are in progress (ISO/CD12782 parts 1-5, 2010) in cooperation between ISO/TC190, CEN TC 345 and CEN TC 292. Methods robustness evaluation is in progress in the EU for construction products as part of CEN/TC 351 for the percolation and monolith leach test. US EPA is validating all above mentioned EPA draft methods through inter-laboratory round-robin testing (Garrabrants et al, 2011). The results of a comparison between the US-EPA 1313 and 1314 protocols and the corresponding CEN protocols are very good (Garrabrants at WASCON 2012 conference). For the analysis of eluates, the emphasis is on multi-substance methods like ICP-OES or ICP-MS for major, minor and trace elements. For anions, like the halogens, sulfate and nitrate, ion-chromatography is the preferred method of choice.

2.2 Data comparison, statistical and modelling tools

For the comparison of leaching test data from multiple materials within a material class and the comparison with regulatory criteria, LeachXS Lite™ (free) has been used, as no other software package either has the data stored in readily accessible format, nor the data handling capabilities necessary to compare results from different leaching test with one another. A full suite of data

handling, statistical evaluation and modelling tools are now more and more user friendly in the database/ expert system LeachXS Pro™ (full version with subscription fee). This expert system contains a significant amount of public domain leaching data that can be used as reference information for own test data of end-users. Statistical calculations have been implemented within LeachXS Pro to allow aggregation of individual data sets (i.e., test results for the same type of material or product) into a benchmark data set for the material or product with average, median, and 90 % confidence intervals. Statistical analyses were performed on $\log^{10}$ transformed concentration results which had been interpolated to the target pH or L/S values designated in the respective leaching test methods. Log transformation is common statistical practice to lessen the impacts of extreme data values for data ranging over orders of magnitude and thus render distributions close to normal, thereby enhancing the suitability of statistical methods based on the normal distribution. In LeachXS Lite it is possible to compare one's own data with such benchmark or reference data for selected materials. Data placed in proper context can be compared with a range of utilisation and disposal regulations from different jurisdictions listed in the regulatory database embedded in both Lite and Pro. The LeachXS Pro™ version contains different environmental impact modelling scenarios making use of test data available in the database (van der Sloot et al, 2008b) as a time-dependent source term. The same source data can be used for different beneficial uses, as well as landfill options.

3 Results

Benchmarks provided for three main material types are given as aggregated data. Figures 1–3 provide an overview of the leaching data on MSWI bottom ash, BOF slag and recycled concrete describing both release as a function of pH (pH dependence test, results of other tests like batch tests) and release as a function of L/S (percolation or column tests and batch tests) for a number of substances. Where applicable, the graphs also indicate the limit values for the Dutch Soil Quality Decree (SQD, 2007) Category 1 (unrestricted use). Many of the datasets are Dutch, German and Danish, but the database includes data on aggregates from a wide range of other EU Member States (Belgium, Finland, France, Italy, Slovenia, Sweden, UK) and countries outside Europe (Taiwan, USA, Australia).

The number tests performed on each material, the number of substances that are analysed in the eluates and the number of eluates produced and analysed per test vary between the different materials and datasets shown in Figures 1–3. In table 1, the number of test data and the references for the data on recycled concrete, BOF slag and MSWI bottom ash are given.

Table 1. Data used as basis for benchmarks

Construction material	**Current number of available datasets**		**Reference**
	Release as a function of pH	**Release as a function of L/S**	
Recycled concrete	109	146	Van der Sloot et al, 2001 & 2011; RIVM database BASIS, 1995; Engelsen et al, 2010.
Basic oxygen furnace (BOF) slag	51	131	Comans et al, 1991; ABANDA database NRWF 2000; RIVM database BASIS, 1995; Huijgen and Comans, 2006; van der Sloot et al, 2010; Bialucha, 2010.
Bottom ash from incineration of household waste	38	175	Meima, 1997; Dijkstra et, 2002; Dijkstra et al, 2008; ABANDA (NRWF), 2000; RIVM database BASIS, 1995; SIWAP, 2008; Lopez-Mesa, 2010; Rendek, 2008; Chen, 2008; van der Sloot et al, 2008a; ECN, 2010.

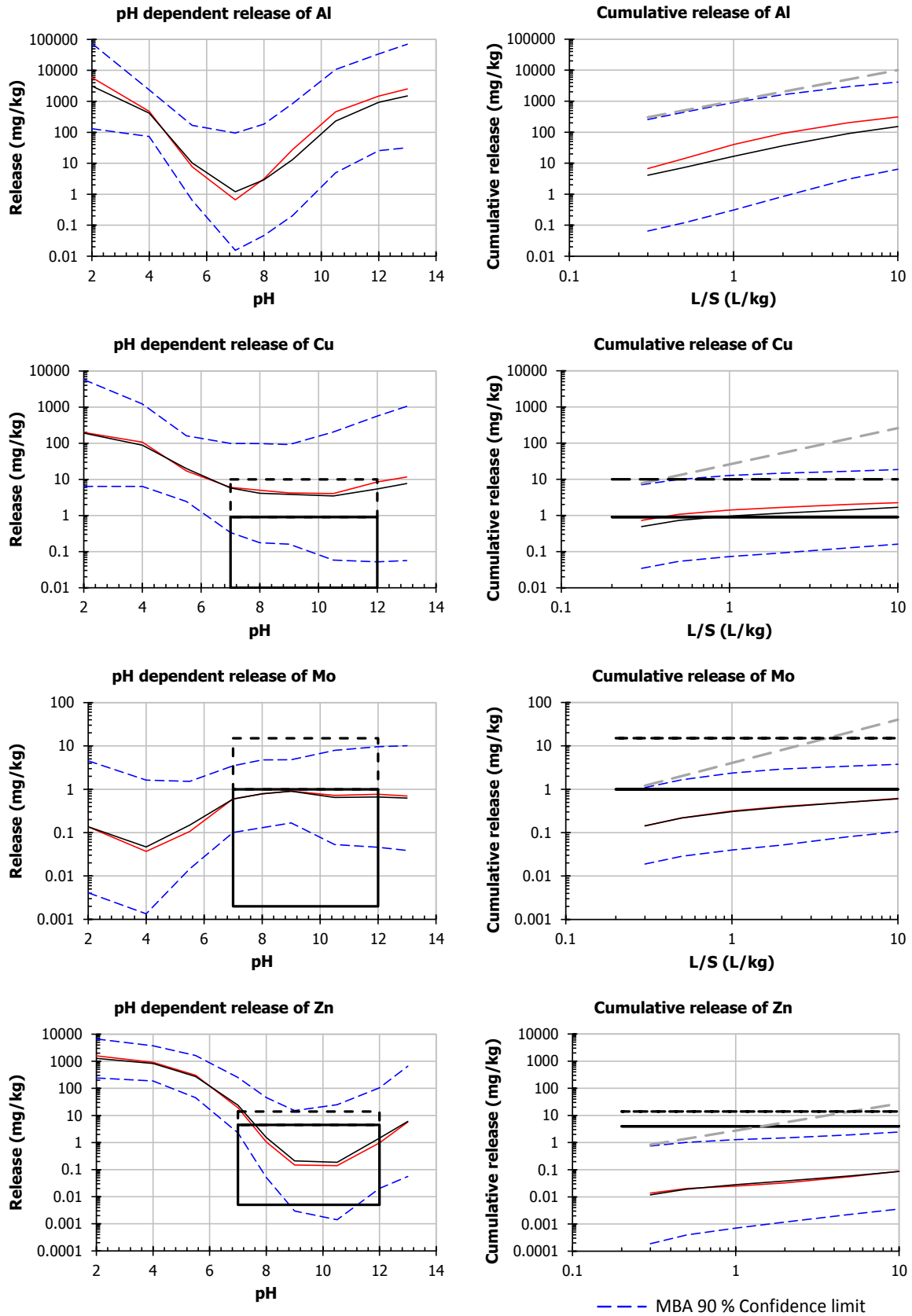

Figure 1. Benchmark for MSWI bottom ash

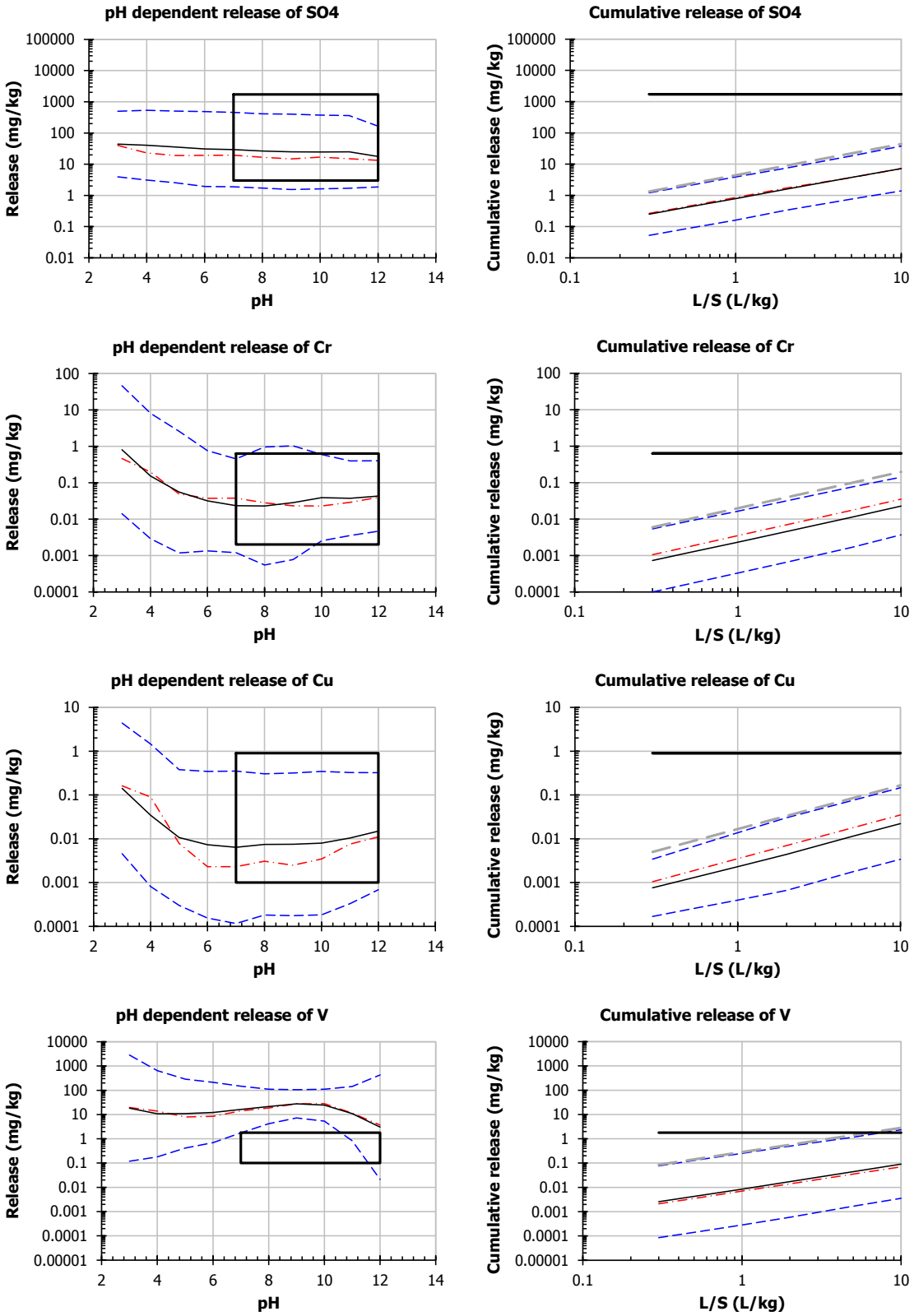

Figure 2. Benchmark for BOF slag

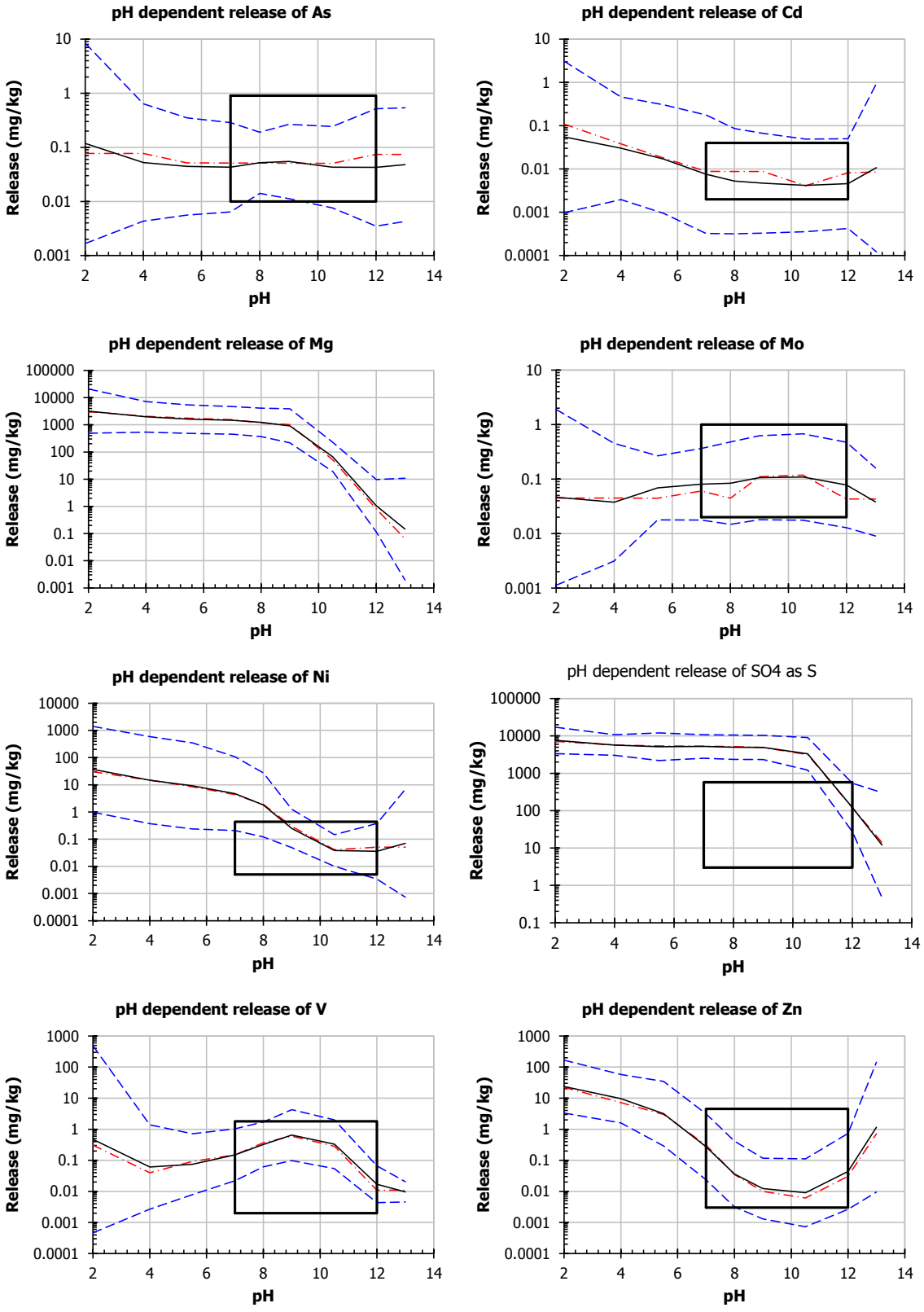

Figure 3. Benchmark for recycled concrete

3.1 Municipal solid waste incinerator bottom ash

In Figure 1 the leaching behaviour of the elements Al, Cu, Mo and Zn are shown for illustration of release of a major component, metals and an oxyanion. The release behaviour as a function of pH shows that changes in exposure conditions (e.g. carbonation) can lead to substantial changes in release. The combination of pH dependent release and release as a function of the L/S (L/kg), which is related to time through the infiltration rate, height and density of the material, provides means to assess release under exposure conditions other than those actually tested. Comparison of the benchmark data with regulatory criteria, such as the Dutch Soil Quality Decree (2007) shows that the quality does not comply with Category 1 for Cu and Mo, but for the most part with Category 2 (under cover). The vertical lines in the box drawn in the pH dependent release graph gives the pH range considered relevant for the application of the material. The upper horizontal line reflects the regulatory criterion (SQD) and the lower horizontal line the limit of detection (DTL). Obviously, the bandwidth becomes narrower, when data for a given incinerator plant is selected.

3.2 Basic oxygen furnace slag

In Figure 2 the leaching behaviour of sulfate, V, Cu and Cr from BOF slag are shown. For the judgment of compliance with regulatory criteria service life, which is reflected largely by the percolation test in this case, all elements fall within the regulatory criteria. However, when the long term exposure under field conditions is considered, it is necessary to consider carbonation and oxidation, which will reduce the pH towards neutral from an initially high pH. In the case of V, the release can potentially increase substantially, as reflected in the pH dependent release behaviour. A further consideration is the particle size effect on release, as this may result in a reduced release due to less exposed surface. Currently, robustness work is ongoing in CEN/TC351 to evaluate these effects.

3.3 Recycled concrete

In Figure 3 the leaching behaviour of sulfate, Mg, As, Cd, Mo, Ni, V and Zn from recycled concrete are given. Here only results for the pH dependence test are given. Like in case of BOF slag neutralisation and particle size effects need to be considered.

The effects of carbonation can be captured in the pH dependence test. However, particle size is more complex due to the mixed release controlling process of diffusion and solubility control. Sulfate and Cr (not shown) can become critical in very fine size reduced material. When concrete from demolition is recycled in concrete application again as aggregate, the issues for release under service life is well within existing regulatory limits. However, when all possible options of using alternative materials are applied in making concrete (alternative fuel in cement production, alternative aggregate, alternative fillers), then in the longer term build-up of leachable substances may occur and limits may be reached even for service life. The current testing tools will allow evaluating such conditions now already, thus preventing critical materials from reaching the market. The leaching tools (pH dependence test in particular) necessary to address consequences of recycling and end of life conditions relevant to the CPR are available.

3.4 Use of benchmark data

The presented benchmarks can be used for the following purposes:

- to check for inconsistencies in the performance of chemical analysis;
- to verify that individual test results are in agreement with the general release behaviour of the material, product or product group;
- for compliance with regulatory requirements over a wider range of experimental conditions;
- as basis for a dossier on a product type or group; and,
- as a basis to derive a source term for modelling of release for impact assessment.

3.5 Consistency between international sources

It is promising to note that products produced in different parts of the world according to similar specifications are showing quite similar leaching behaviour. This has been shown to be the case for cement mortars (van der Sloot et al, 2012) as well as for MSWI bottom ash. This implies that when the testing approach is the same, data generated in different parts of the world can be used to build a common reference base for a wide range of materials and products for which decisions on environmental quality are needed.

4 Conclusions

- The new health and safety requirements for construction products in relation to CE marking require data on leaching of construction products.
- Horizontal leaching methods for construction products are in development in CEN/TC351, which distinguish between granular, monolithic and coarse granular products.
- Very similar characterisation leaching methods are in development in CEN and by US EPA.
- Relevant historic data on leaching of a wide range of materials and construction products are available in the leaching database linked to the Leaching Expert System – LeachXS Lite.
- For some product types, such as MSWI bottom ash, BOF steel slag and recycled concrete, sufficient data are available to statistically treat the data to create a benchmark for leaching behaviour of these materials.
- The benchmarks can be used to place end-user data in perspective, judge release behaviour in relation to available regulations and provide a basis for drafting WFT dossiers.

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