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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: WR0108 (WRT219)
2. Project title: UK support for EU LEACHXS expert database on waste characterisation
3. Contractor organisation(s): WRc plc
   ECN (Energy Centre Netherlands)
4. Total Defra project costs (agreed fixed price): £ 99,000
5. Project: start date ..... 01 September 2005
   end date ..... 31 March 2008

6. It is Defra's intention to publish this form.
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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

SUMMARY

Background
Strategies to manage the environmental challenges posed by wastes require good quality data on waste characteristics such as leachability and composition. Public domain datasets for UK wastes tend to be limited in number and extent and those that are available are stored in disparate locations and media. The data cannot easily be evaluated or compared either with other UK data or with more extensive non-UK datasets. Information on the quality of residues arising from new waste technologies and treatments are particularly sparse.

LeachXS© is an expert system for managing and modelling waste characterisation data. It has been developed by ECN (Netherlands), DHI (Denmark) and Vanderbilt University (US), contains 5M€ waste data and incorporates:

- an Access database of public domain information on leachability and composition,
- data management tools allowing comparison of data by waste type or constituent, and
- a powerful geochemical speciation/transport model, "ORCHESTRA".

Objectives
WRc and ECN obtained Defra funding under the "understanding waste composition and trends" theme of the Waste Evidence programme:

- to provide a national waste characterisation database focusing on composition and leachability, as a national satellite database to *EUleachXS©;* and
- to further develop data management tools to increase the value of the dataset.

Research Methods
In outline, the following principal steps have been undertaken during this two year project:

- Identify candidate UK datasets and arrange access to data on waste characteristics.
- Install database and obtain training in preparing and uploading data into leachXS, become familiar with basic data management and expert system tools.
- Further develop expert tools (ECN).
- Collate publicly available German leaching test data (ECN).
- Deliver a basic user guide and database

Outcome
LeachXS© is a powerful secondary research tool containing appropriate publicly available data on the composition and leachability of approximately 2000 European waste samples including data for UK and German wastes collated for this project. The UK dataset can therefore be interrogated by end-users in the context of the wider, pan-European leachXS database.

Simple data management tools enable the novice user to rapidly compare the characteristics of different wastes, allowing for example comparison of characteristics of :

- generic waste types from different plants (e.g. slags from different locations);
- residues from different treatment technologies (e.g. the MSW gasification residues versus MSW incineration residues);
- inputs and outputs from a treatment plant to determine impact of treatment on pollution potential;
- UK wastes with potentially more extensive datasets for similar non-UK wastes.

The data can therefore be used for future reference and interrogation. This might encompass data collation for pollution potential inventories, as source term data for environmental risk assessments or to compare performance and environmental benefits provided by different treatment plants. Expert tools are available for the management, interpretation and scenario-specific usage of the data. More experienced users can undertake geochemical modelling in ORCHESTRA. This may be to establish geochemical fingerprints of waste types or to predict long-term emissions, for example, after landfilling or in an environmental reuse context.

The principal benefit to Defra from this project, is the collation of existing data into a single system which can be used for future interrogation at a technical or policy level. As ECN, VB and DHI continue to develop the functionality of the system, so the full potential for the UK dataset will be extended, to the benefit of policy-makers, researchers and industry.

Key Suggestions
The dataset contains past and current data, the most recent being information generated in 2008. In order to retain currency in the dataset the leachXS licence should be maintained and the database updated periodically. This will allow the dataset and assessments made on the data to keep abreast of developments in new technologies and to drivers for managing wastes in a sustainable way.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the scientific objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

1. Introduction

1.1 Background

Strategies to manage environmental challenges, such as climate change and sustainability need good quality data on waste composition. Waste characteristics dictate waste management options, and the use of the data underpins science on, for example, control of contaminants and emissions to the environment and resource flow through the economy. The output from this project contributes towards that evidence-base and falls into the *"understanding waste composition and trends"* theme of the Waste and Resources Evidence Programme. UK

datasets for non-MSW waste streams do exist, but greater value can be obtained from them if collated in a single, public domain, interrogable database.

The *LeachXS*© expert system has been developed by ECN (Netherlands), DHI (Denmark) and Vanderbilt University (US). It already contains 5M€ worth of waste data and incorporates:

- an Access database of public domain information on leachability and composition,
- data management tools allowing comparison of data by waste type or constituent, and
- ORCHESTRA, a powerful geochemical speciation/transport model.

1.2 Objectives

To develop a UK-wide database of public domain waste characterisation and landfilled waste and leachate data, providing the UK satellite for a future funding proposal to develop a pan-European database / expert system for evaluating data on composition and potential environmental impact through leaching for a wider range of wastes.

The specific objectives are as follows:

1. To consolidate and develop the background information to support a detailed working plan for the project
2. To conduct all tasks concerning the installation and training requirements for operating the EU leachXS© satellite database and associated interpretative tools.
3. To identify candidate UK datasets (including waste characteristics and regulatory limit values) and arrange access to the best reliable data.
4. To develop a demonstration of the systems and the developing evaluation tools.
5. To develop expertise in the use of the system and make further development to the early prototype, coordinating this work with the EU-funded project HORIZONTAL programme (ECN).
6. To develop and deliver a structured approach to the collation, verification and uploading of agreed datasets retaining an audit trail of data collection as a quality assurance measure. A report of summary statistics delivered as an annex to the final report.
7. Prepare and upload a 'read me' user guide to the database for the benefit of new users.
8. To deliver the database, in the form of a dedicated laptop with software installed to drive the system along with a copy of the agreed final report.

1.3 Report structure

As the principal objective is the delivery of a database, this final report will summarise the functionality of the system, the datasets that are included within it and some examples of how the tools can be used by Defra. A report of summary statistics for the database, guidance on the use of the system and examples of application at an expert level are appended as follows:

Annex A – Summary database statistics.
Annex B – User manuals.
Annex C – Example plots.
Annex D – Modelling tools.

2. The leachXS© expert system

2.1 Background

The *LeachXS* expert system has been developed by ECN (Netherlands), DHI (Denmark) and Vanderbilt University (US). It already contains 5M€ waste data and incorporates the following elements linked as shown in Figure 1:

- an Access database of public domain information on leachability and composition,
- data management tools allowing comparison of data by waste type or constituent, and
- ORCHESTRA, a powerful geochemical speciation/transport model.

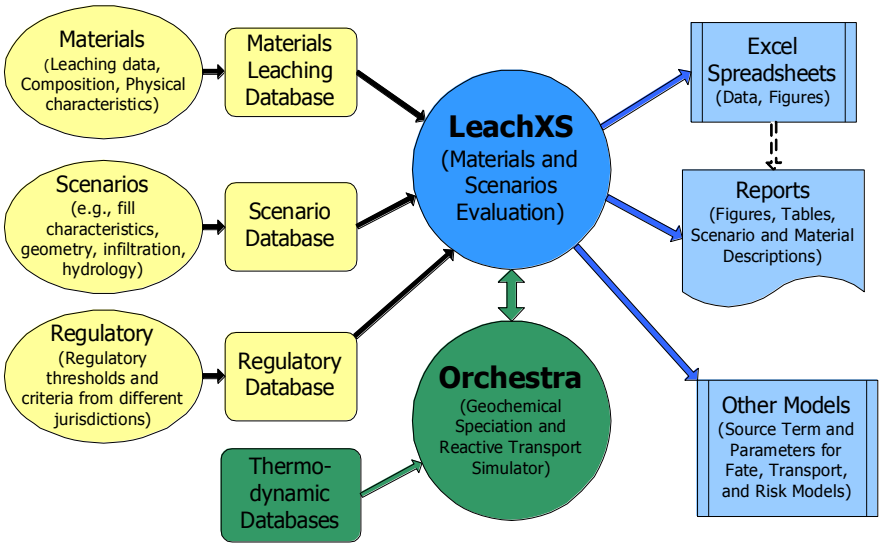

Figure 1: Schematic of leachXS

Background to the operation of the system is detailed in van der Sloot, *et al.*, 2003 and 2006 and summarised here: http://www.leachxs.org/LeachXSFlyer.pdf). LeachXS© is backed up by a powerful geochemical modelling framework, ORCHESTRA, which offers the potential for predicting long-term emissions as undertaken for the Sustainable Landfill project (van Zomeren *et al.*, 2005).

Members of the project team were trained in the use of the systems at the beginning of the project with two further training sessions following significant upgrades to the system. The current version of the leachXS© user manual which provides detailed instructions to use is appended in Annex B1. Following verification of the datasets (Section 2.2), the data were converted into a format suitable for uploading into leachXS©. This tended to be a time-consuming exercise. A recent upgrade to leachXS© includes a data exchange process which has significantly improved data upload. Instructions on the use of the data exchange tool are provided in Annex B2.

2.2 Technical development of leachXS© by ECN

ECN are subcontracted to provide technical back-up and training to WRc and to undertake development of leachXS© functionality that will benefit UK end users.

Development to the user interface, data management tools and ORCHESTRA have been made through two principal upgrades as follows:

September 2007

- Improved full mechanistic model for percolation test data using dual porosity to account for incomplete wash-out of soluble components.
- New statistics option to evaluate leaching data sets including output function.
- Option to insert own judgment lines in pH dependence and upflow percolation test data displays (useful for defining boundaries and domains).
- Improvements to modelling of pH dependence test data:
  - better fitting routine for dissolved organic carbon
  - option to include column test data in the pH graph
  - option to predict leaching behaviour at any L/S (low L/S) with selected mineral and adsorption parameter set
- Improved option to predict leaching behaviour of materials mixtures based on pH stat data for individual streams.
- Full mechanistic prediction of dynamic monolith leach test data (input tortuosity, a parameter to select the cell thickness and a chemical speciation fingerprint as obtained from pH dependence test) – both tank test with renewal and test with continuous liquid flow.
- Impact scenario based on new Building Materials Decree (2006) modelling approach.
- New improved input routine for own test data (broad spectrum of test).
- Full mechanistic scenario for material soil interaction (percolation mode.)
- Predominance diagram generation from case files
- New case file structure (independent from other model runs, including all information to run the case on any LeachXS© – Orchestra version)

- improved reporting functions
- statistical data evaluation for pH dependence, percolation and monolith leaching
- static diffusion model using material info from pH dependence test runs
- improved handling of particulate and dissolved organic matter (these were independent before and are now linked in a mass balance)
- impact scenario for soil and groundwater based on the new Building Materials Decree (with an option to import your own column data - Co and kappa values)
- 3-layer percolation model based on selection of materials from pH dependence test results

In addition example runs using LeachXS were provided that can be used as a template for user-specific scenarios:

- comparison cases for almost any type of leaching test result
- chemical speciation runs for a few selected matrices (bottom ash, mixed MSW, compost, stabilized waste, coal fly ash, cement mortar)
- percolation runs for a selection of the aforementioned matrices
- mixing of materials
- monolith leaching
- static diffusion

3. Collation of datasets

3.1 UK data identification and conversion process

Members of the UK academic and consultancy community were contacted in order to determine whether publicly available data on the composition and leachability of wastes were available, and if so whether they were suitable for inclusion in the database.

Some of the datasets were excluded from further consideration due to the following factors:

- Lack of relevance – component analysis (e.g. glass and metal) or physical characteristics (grading) rather than chemical composition;

- Lack of leachability data - necessary to anchor the dataset into the leachXS© database;

- Absence of usable test data – inability to compare data with current widely used tests, either because the test methods were specific to a testing scenario, or because laboratory data needed to convert the leachability data back to mg/kg were not available.

- Age – some historic data were considered unlikely to add value to the national dataset, either due to the subject matter or because the test data were not directly usable (see above).

- Lack of interest - significant effort to repeat requests for information was not warranted.

However, the national dataset has benefited from the inclusion of many datasets, principally the outcome of research funded by the Environment Agency, landfill tax or Defra. In addition, WRc has been particularly active in this field since the 1990s and has obtained permission for inclusion of commercial-in-confidence characterisation from several parties.

3.2 UK datasets

The following datasets have been uploaded into leachXS, totalling 148 samples.

- *Defra WR0110 Characterisation of residues from industrial processes and waste treatment* (Defra, 2009). Of all the datasets incorporated into leachXS©, the data from the parallel Defra research project arguably makes the most significant contribution to the national dataset on composition and leachability of wastes. The data relate to samples collected in 2006-2008 and were subjected to the most comprehensive testing exercises. Data for the following waste streams have been uploaded:

    - Organic wastes - 40 input and output samples from a range of treatment processes (mechanical biological (MBT), mechanical heat (MHT) treatments, composting, anaerobic digestion) for a wide

range of commercial, source-segregated municipal and untreated municipal solid wastes have been assessed with respect to leachability, composition and biodegradability**.** Selected organic wastes have been subjected to upflow percolation tests in order to derive kappa values for landfill source term modelling. These represent three decomposition endpoints: mature CLO (compost-like output), most mature MSW-derived CLO, immature MSW-derived CLO) and a 75% mature anaerobically digested MSW and sewage sludge cake. LeachXS will enable comparison of the characteristics of wastes at the boundaries of the waste/treatment matrix. The initial leaching tests provide data on the consistency of leachability of similar CLOs within the envelope.

- Filter cakes from physico-chemical treatment plants: non-hazardous (6) and hazardous (6) filter cakes from a liquid waste treatment facility. All samples were screened using leachability landfill WAC parameters to indicate variability of key leachable contaminants. Comprehensive characterisation of one composite sample for each stream included: aqua regia metals, maximum availability for leaching, pH dependence leachability testing and upflow percolation testing.

- Treated municipal solid waste incineration (MSWI) air pollution control (APC) treatment filter cakes (6). All samples were screened using leachability landfill WAC parameters to indicate variability of key leachable contaminants. Comprehensive characterisation of one composite sample for each stream included: aqua regia metals, maximum availability for leaching, pH dependence leachability testing and upflow percolation testing.

- *Gasification residues - full scale European MSW gasification plant*. Bottom ash (2) and APC residues (2) - comprehensive characterisation of each: aqua regia metals, maximum availability for leaching, pH dependence leachability testing and upflow percolation testing.

- *Gasification residues: small scale UK gasification unit, burning chipped wood waste*. WAC parameters only.

- *Stabilised waste samples*. Specifications for three cement stabilised waste treatment mixes from a European plant were agreed and cores allowed to cure for one month. Testing focused on the tank leaching test of the monolithic samples and the batch leaching test on crushed samples allowing performance of the UK WAC for monolithic wastes to be assessed against the EU/UK granular WAC to support the parallel Defra review of UK landfill WAC for monolithic waste. Test data also included pH dependence and maximum availability for leaching and Hg porosimetry testing.

Data have also been collated from older research projects as follows:

- Graham, A. *et al.,* (2006) WRc; UKWIR-funded sewage grits and sewer screenings data: leachability (batch/upflow percolation/pH dependence, maximum availability), composition (metals, ions and nutrients, trace organic compounds: PCBs, PAHs, BTEX, TPH). 15 screening samples and 4 samples for comprehensive characterisation.

- Environment Agency (2002); Evaluation of waste project: foundry sands (4), steel slags (2), pulverised fuel ash (3), MSW incineration bottom ash (2), sewage sludge incineration ash (1), Cr sludge (1), cement kiln dust (1). Triplicate testing for total metals and major ions and batch leaching (L/S2 and L/S10), single testing for maximum availability for leaching.

- Lewin, K. *et al.,* (2005 and 2006)*;* Dti/ETSU properties and characteristics of municipal solid waste incineration (MSWI) residues (Lewin *et al.,* 2005 and 2006): bottom ash, cyclone dust and air pollution control (APC) residues from 3 plants in 1994 and 1995.

- Blackmore, K. *et al*, (1998); Brogborough landfill test cell leachate; sanitary parameters and metals from 6 test cells 1986 to 2002.

- Lewin and Young, (2005); Resource Recovery Forum APC residue characterisation: leachability (batch/upflow percolation/pH dependence, maximum availability for leaching/tank diffusion test on cores), composition (metals, TOC, trace organic compounds: PCBs, PAHs, dioxins, furans) - 3 screening samples and 1 sample for comprehensive characterisation.

- Graham *et al.,* (2002/03) Jersey Public Services Department MSW IBA characterisation 2002/3: leachability (batch, upflow, pH dependence), composition (metals, TOC).

- Graham, A and Lewin, K. (2003) Jersey Bottom Ash Characterisation 2003: Full Characterisation. UC6591. Jersey Public Service Department

- Chambers *et al.,* (2004), Godbold *et al.,* (2006); Thames Water Landfill Tax Committee projects: 3 samples of grits and screenings (batch leaching, availability, composition) and bricks from water works sludge (batch leaching, composition).

- Blakey N.C., Reynolds P.J., Bradshaw K. and Young C.P. (1996). Landfill 2000: A field trial of accelerated waste stabilisation. Final report to the UK Department of the Environment (CWM 050/96).

- Robinson, H.D., Knox, K. (2004): Testing of residues from incineration of municipal solid waste; Environment Agency Science report (P1-494/SR2)

- Data provided by Imperial College: leachability data for solidified waste, metal plating wastes and sintered IBA from 4 PhD theses (Ng (1992); Leong (1993); Potter (1993); Crookshanks (1993)), two reports undertaken as private consultancy: Characterisation of stabilised hazardous waste (Cheeseman (1996)) and characterisation of flue gas desulphurisation product (Cheeseman (1992)).

3.3 German characterisation datasets

The opportunity arose for Defra to support the collation of output from large German studies so that this resource could also be available to Defra via leachXS©. The two main projects were:

- The German Sickerwasserprognose (SiWaP) project: a large joint BMBF (Federal Ministry of Education and Research) project investigated the use of materials in construction and characterization of waste and generated a large body of laboratory (batch and column test) and lysimeter data on 12 materials over 4.5 years to provide a basis for regulatory decisions.

- LANUV NRW (Ministry for Nature, Environment and Consumer Protection): data were collected on a wide range of materials over a period of many years. The LANUV dataset is more extensive than that available via the website of ABANDA LANUV (http://www.abanda.org).

The sample and test types are summarised in Annex A. Data for approximately 1500 samples have been generated by the German studies.

ECN collated and imported the data into leachXS to allow comparison of laboratory test data, lysimeter measurements and eluate measurements in the field on a broad range of materials. Speciation modelling for a selection of relevant materials (e.g. bottom ash, coal fly ash, contaminated soil, construction debris) was then undertaken. Mechanistic modelling release from a few selected materials was also conducted in a percolation scenario as a basis for impact modelling. Papers are being prepared for publication.

3.4 Summary statistics

Summary statistics for the three combined databases (leachXS© public domain data, UK data and German data) are provided as an Excel spreadsheet in Annex A. In summary, data for approximately 1650 samples of waste have been collated for a range of laboratory and/or field tests for the UK and Germany, in a total database of 2038 samples.

4. Application of leachXS©

LeachXS is a powerful resource for secondary research, both through data evaluation in the context of wider data sources and through the application of the geochemical modelling programme, ORCHESTRA. Some examples of its application are provided below.

4.1 Placing batch leaching test data in context

An example of the power of the leachXS database is the evidence it provides against taking some leaching test data at face value. For example, assessments of risk to groundwater and surface water from the leachability of waste materials will commonly rely on the results of batch leaching tests (e.g. BS EN 12457-2 or 3), where these are the only data available, and the comparison of these L/S10 datasets with benchmarks for surface and groundwater. However, the BS EN 12457 leaching tests are undertaken at natural pH, i.e. without pH control during testing, and therefore the leachability will depend on the pH of the material being tested. In comparison the pH of controlled waters is generally within the range pH 7-8. For a determinand with strong pH-dependent leaching, the leachability exhibited at the pH of the material may be several orders higher than the pH that would prevail in the receiving controlled waters. For example, the amphoteric metals Pb and Zn demonstrate classic U-shaped leaching, very high leaching at low and high pH values but minimum leachability at pH 7-8.

Strong pH dependent leaching is exhibited by aluminium in bottom ashes from MSW EfW plants. Typically the results of L/S10 leaching are in tens of mg/l whereas a tentative Environmental Quality Standard for Al has been derived of just 0.15 mg Al/l at >pH6.5, suggesting that without significant controls to prevent leachate release and/or significant opportunities for dilution, contamination of surface water could be expected.

Figure 2 presents leachability data for IBA from a range of European MSW EfW plants plotted using the statistical package of leachXS. Eluate concentrations derived from L/S10 pH dependent leaching tests (e.g. CEN/TS 14429) and compliance leaching tests (e.g. BS EN 12457-2) have been plotted against eluate pH. The plot shows the measured solubility of aluminium leached from MSW IBA at different pH values, clearly indicating that measured dissolved levels follow the predictions of theory (at pH 6-8 aluminium hydroxide is barely soluble) and confirming the predicted minimum solubility at neutral pH. The levels of dissolved Al that could be leached at pH 9-11 could not remain in solution at the typical pH of the receiving surface water, aluminium would tend to rapidly precipitate out as salts and a surface water contamination issue would be unlikely.

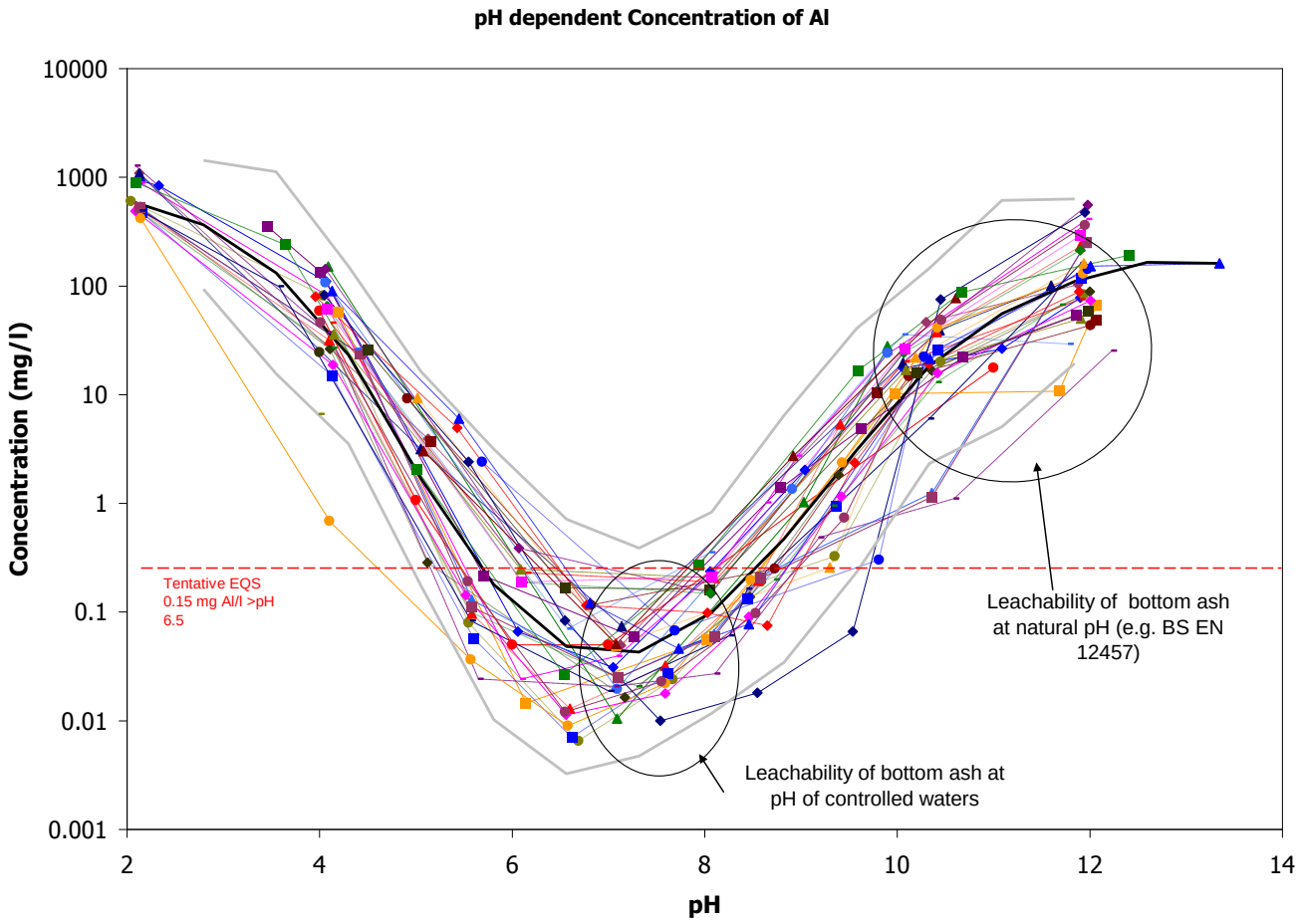

Figure 2: pH dependent aluminium leachability data for IBA from leachXS©

Leaching test data can be compared for different materials, with summary statistical data produced using the LeachXS statistics function. This will summarise a number of datasets and provide details on confidence intervals for individual concentrations or ranges of concentrations. This function will also confirm whether a particular dataset is statistically different from a base dataset. The statistics function has been applied to the data plotted in Figure 2.

ORCHESTRA, the powerful geochemical/transport model integrated with leachXS offers a much more sophisticated means of predicting dissolved metal leachability. ECN have published several papers on the application of ORCHESTRA to incineration bottom ash characterisation data including Dijkstra *et al.*, 2006(a and b), 2008.

4.2 Comparing the leaching behaviour of different wastes

Under Defra-funded project WR0110, comprehensive characterisation data were obtained for MSW gasification residues. Little information had hitherto been publicly available on gasification residue characteristics. LeachXS© enabled rapid comparison with the extensive dataset for bottom ash from MSW incineration plants.

Figure 3 plots the lead eluate concentrations from pH dependence tests and batch leaching test against eluate pH for a number of MSW incineration bottom ashes (IBA). The strong U-shaped pH dependence observed in Figure 2 is also exhibited, as expected, for lead. The similar leaching profile for the gasification residue indicates that the mechanism controlling lead leachability is the same for both generic residues. Also of interest is the measured concentration, i.e. level of lead release relative to that from IBA. The concentration of lead leached is within the range of MSWI bottom ashes. More sampling and testing is required to confirm whether other gasification ashes leach at levels towards the lower end of the IBA concentration ranges.

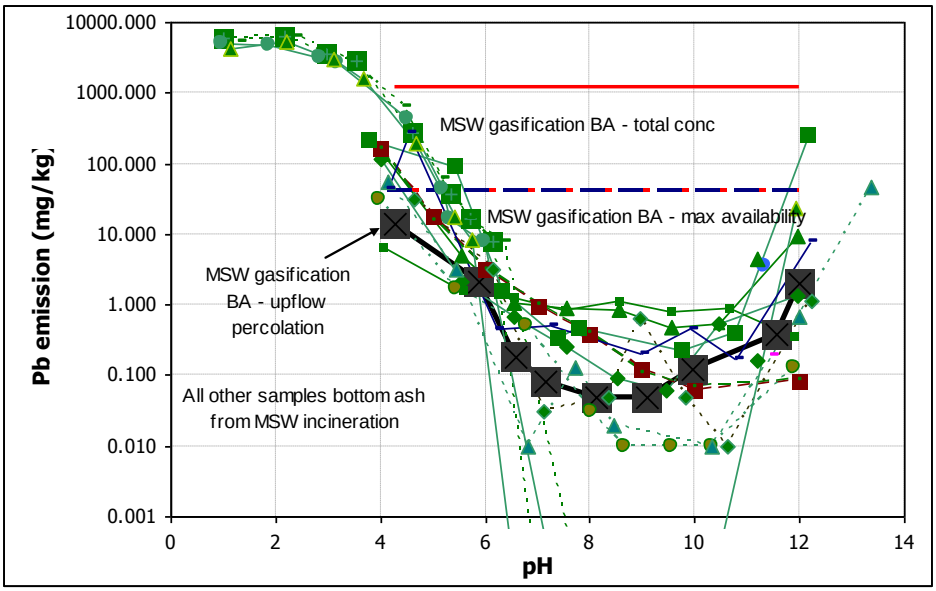

Figure 3: Lead leachability of MSW gasification bottom ash in context of leachXS© data for MSW incineration bottom ash

4.3 Comparing the leaching behaviour of different wastes/types of treatment

Defra funded project WR0110 generated data on air pollution control residues from MSW gasification and MSWI APC residues that had been subjected to physico-chemical treatment. Plotting tools within leachXS were used to rapidly compare the leachability of these residues with untreated MSWI APC residues. Figure 4 presents total concentrations, maximum availability and pH dependent leachability. In the key pH 6-12 range, the cadmium, copper and zinc leachability of untreated gasification APC residues is at least an order of magnitude lower than for untreated APC residues from MSW incineration. Data for treated MSWI APC residues fall between the two. These examples typify the relative levels of release from the three generic waste types. The highest reported concentrations leached from the untreated MSWI APC residues, followed by the treated MSWI APC residues with the APC residues from MSW gasification leaching at lower levels.

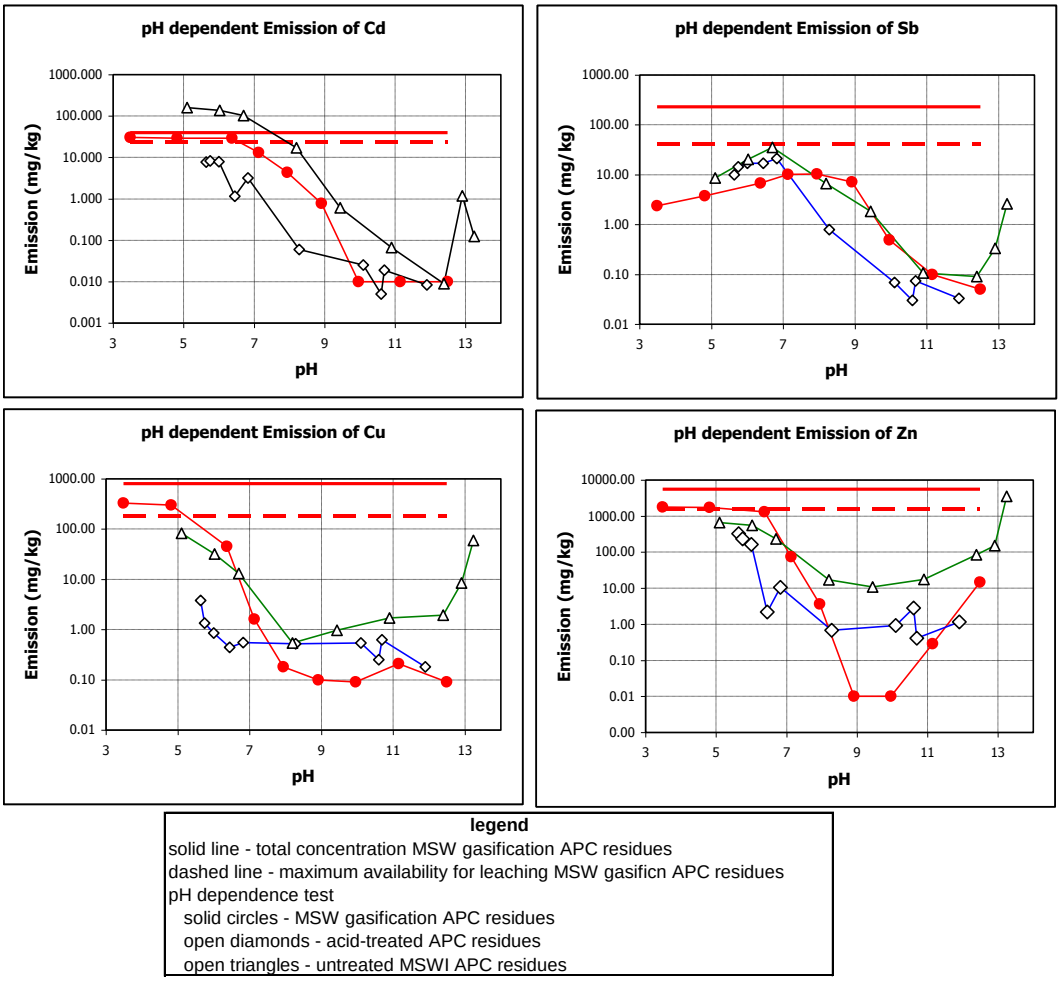

Figure 4: Comparison of pH dependent leachability of APC residues from MSW gasification with untreated and treated APC residues from MSW incineration.

4.4 Further examples of geochemical modelling

Defra WR0110 also generated characterisation data for cement stabilised hazardous wastes which were used to support the review of monolithic waste acceptance criteria (Defra, 2009). The characterisation exercise included the use of the tank test NEN 7375, ECN. The chemistry of the stabilization process has been assessed in greater detail by ECN using the geochemical modelling functions of ORCHESTRA within leachXS©. ECN's detailed technical evaluation and demonstration of the power of their modelling tools is provided in Annex D. Further assessment of stabilisation wastes using the leachXS©/ORCHESTRA tools are provided in van der Sloot *et al.,* 2007.

5. Outcome

The project has delivered a database populated with national waste composition/characterisation data from the UK. It provides access to public domain European data on the leachability of wastes, including new German data. The data collection exercise has focused on obtaining the best value from existing datasets on non-MSW waste streams in the UK, uploading them into databases with expert tools for the management, interpretation and scenario-specific usage of the data. The data management and interpretive tools have also undergone considerable development with the support of this project reducing the level of expertise required to run the powerful geochemical modelling framework, ORCHESTRA.

The test data have been exported to the national satellite database of the leachXS system. The database can be interrogated at several levels by a range of users allowing the leaching behaviour and composition of specific plant outputs to be compared and the characteristics of generic waste streams to be evaluated on a national and, ultimately, European basis, including comparison of data on residues from new and established treatment technologies.

6. Suggestions

The dataset contains information generated in 2008. In order to retain currency the dataset should be maintained and updated periodically to keep abreast with the new data and new wastes arising in response to drivers for managing wastes in a sustainable way.

As LeachXS© requires data in mg/l, data in mg/kg may be unsuitable for inclusion if full laboratory testing details are not available, and we recommend that all laboratory data relating to sample size, moisture content and leachant volume are retained with the data, even when mg/kg conversion has been carried out.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

Blakey NC, Reynolds PJ, Bradshaw K and Young CP (1996). Landfill 2000: A field trial of accelerated waste stabilisation. Final report to the UK Department of the Environment (CWM 050/96).

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