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Reuse of “Waste” in Making Building Products – Methodology and Evaluation

16th International Waste Management & Landfill Symposium

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October 4, 2017

Outline

- Introduction
- US EPA's definition of beneficial use
- Methodology to evaluate "waste" for beneficial use
- Use of LEAF in evaluating concern for leaching of constituents of concern
- Next steps
- LEAF bibliography

How can we "utilize" industrial by-products as alternative materials while ensuring safety of ~~environmental and~~ public health and the environment!?

- There are damage cases from indiscriminate use of coal ash (https://www.epa.gov/coalash/coal-ash-rule) and other industrial by-products
- This prompted US EPA to develop criteria for defining beneficial use
- Initial focus is on the larger uses of industrial by-products which is coal fly ash and wet scrubber flue gas desulfurization (FGD) gypsum
  - The amount of coal ash generated in 2016 was 117 million short tons; 52% utilized (www.acaa-usa.org)
  - Multiple potential applications and sources of environmental release
  - Because of end product's contact with land and water, pathway of primary concern is release of inorganics to drinking or surface waters

EPA's Beneficial Use Definition

- Virtually all industrial sectors generate by-products that are typically discarded but may be used to replace natural resources and conserve energy
- EPA has defined beneficial use as the incorporation of an industrial material into a commercial product that:

1) provides functional benefit
2) meets relevant design specifications and performance standards for the proposed use
3) replaces virgin, raw materials in a product already on the market and
4) is implemented in an environmentally acceptable manner

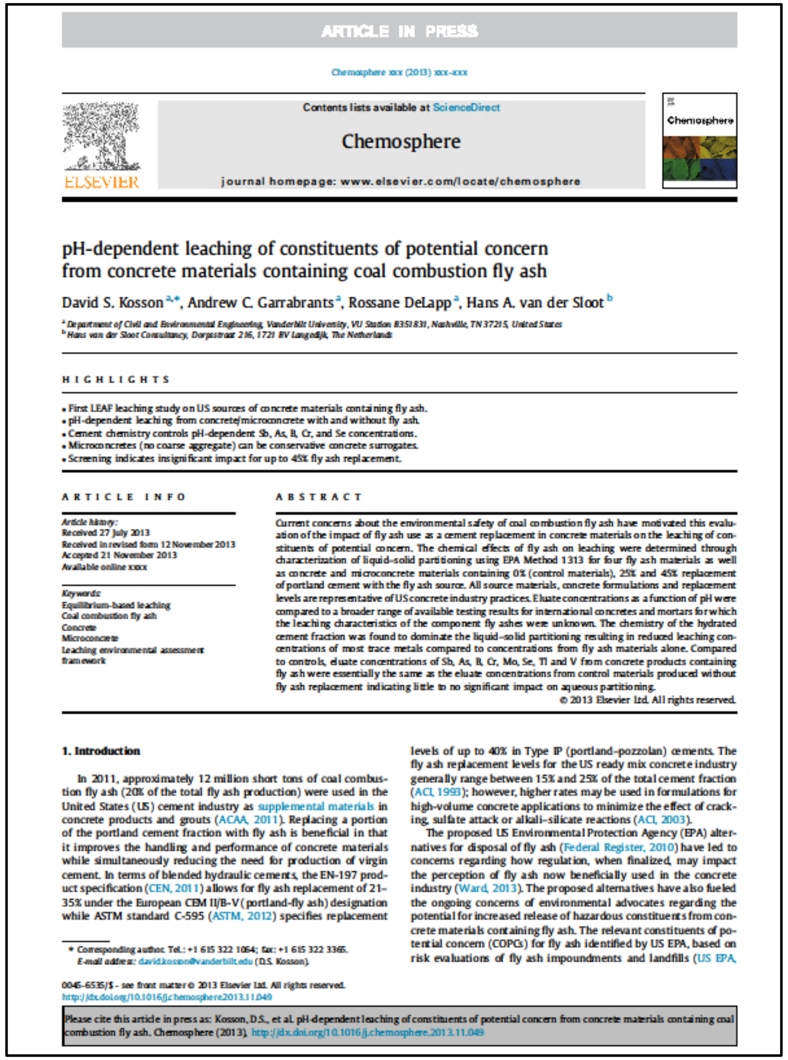

Photo by Frank Greenwell
Photo by Menomonee Valley Partners, Inc.

EPA United States Environmental Protection Agency

How does leaching of cementitious materials compare between use of portland cement or coal fly ash?

- 2012 US EPA Report compared LEAF data from:
  - 31 cement mortar and concrete samples containing coal fly ash
  - 21 cement and mortar samples that did not contain coal fly ash
- Results indicate that large portion of coal fly ashes currently being produced can be used in cement and concrete formulations without causing potential adverse environmental impacts

Verification of Findings on example coal fly ashes being marketed for this application



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Chemosphere xxx (2013) xxx–xxx

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

pH-dependent leaching of constituents of potential concern from concrete materials containing coal combustion fly ash

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HIGHLIGHTS

- First LEAF leaching study on US sources of concrete materials containing fly ash.
- pH-dependent leaching from concrete/microconcrete with and without fly ash.
- Cement chemistry controls pH-dependent Sb, As, B, Cr, and Se concentrations.
- Microconcretes (no coarse aggregate) can be conservative concrete surrogates.
- Screening indicates insignificant impact for up to 45% fly ash replacement.

ARTICLE INFO

Article history:
Received 27 July 2013
Received in revised form 12 November 2013
Accepted 21 November 2013
Available online xxxx

Keywords:
Equilibrium-based leaching
Coal combustion fly ash
Concrete
Microconcrete
Leaching environmental assessment framework

ABSTRACT

Current concerns about the environmental safety of coal combustion fly ash have motivated this evaluation of the impact of fly ash use as a cement replacement in concrete materials on the leaching of constituents of potential concern. The chemical effects of fly ash on leaching were determined through characterization of liquid–solid partitioning using EPA Method 1313 for four fly ash materials as well as concrete and microconcrete materials containing 0% (control materials), 25% and 45% replacement of portland cement with the fly ash source. All source materials, concrete formulations and replacement levels are representative of US concrete industry practices. Eluate concentrations as a function of pH were compared to a broader range of available testing results for international concretes and mortars for which the leaching characteristics of the component fly ashes were unknown. The chemistry of the hydrated cement fraction was found to dominate the liquid–solid partitioning resulting in reduced leaching concentrations of most trace metals compared to concentrations from fly ash materials alone. Compared to controls, eluate concentrations of Sb, As, B, Cr, Mo, Se, Tl and V from concrete products containing fly ash were essentially the same as the eluate concentrations from control materials produced without fly ash replacement indicating little to no significant impact on aqueous partitioning.

1. Introduction

In 2011, approximately 12 million short tons of coal combustion fly ash (20% of the total fly ash production) were used in the United States (US) cement industry as supplemental materials in concrete products and grouts (ACAA, 2011). Replacing a portion of the portland cement fraction with fly ash is beneficial in that it improves the handling and performance of concrete materials while simultaneously reducing the need for production of virgin cement. In terms of blended hydraulic cements, the EN-197 product specification (CEN, 2011) allows for fly ash replacement of 21–35% under the European CEM II/B-V (portland-fly ash) designation while ASTM standard C-595 (ASTM, 2012) specifies replacement levels of up to 40% in Type IP (portland–pozzolan) cements. The fly ash replacement levels for the US ready mix concrete industry generally range between 15% and 25% of the total cement fraction (ACI, 1993); however, higher rates may be used in formulations for high-volume concrete applications to minimize the effect of cracking, sulfate attack or alkali–silicate reactions (ACI, 2003).

The proposed US Environmental Protection Agency (EPA) alternatives for disposal of fly ash (Federal Register, 2010) have led to concerns regarding how regulation, when finalized, may impact the perception of fly ash now beneficially used in the concrete industry (Ward, 2013). The proposed alternatives have also fueled the ongoing concerns of environmental advocates regarding the potential for increased release of hazardous constituents from concrete materials containing fly ash. The relevant constituents of potential concern (COPCs) for fly ash identified by US EPA, based on risk evaluations of fly ash impoundments and landfills (US EPA,

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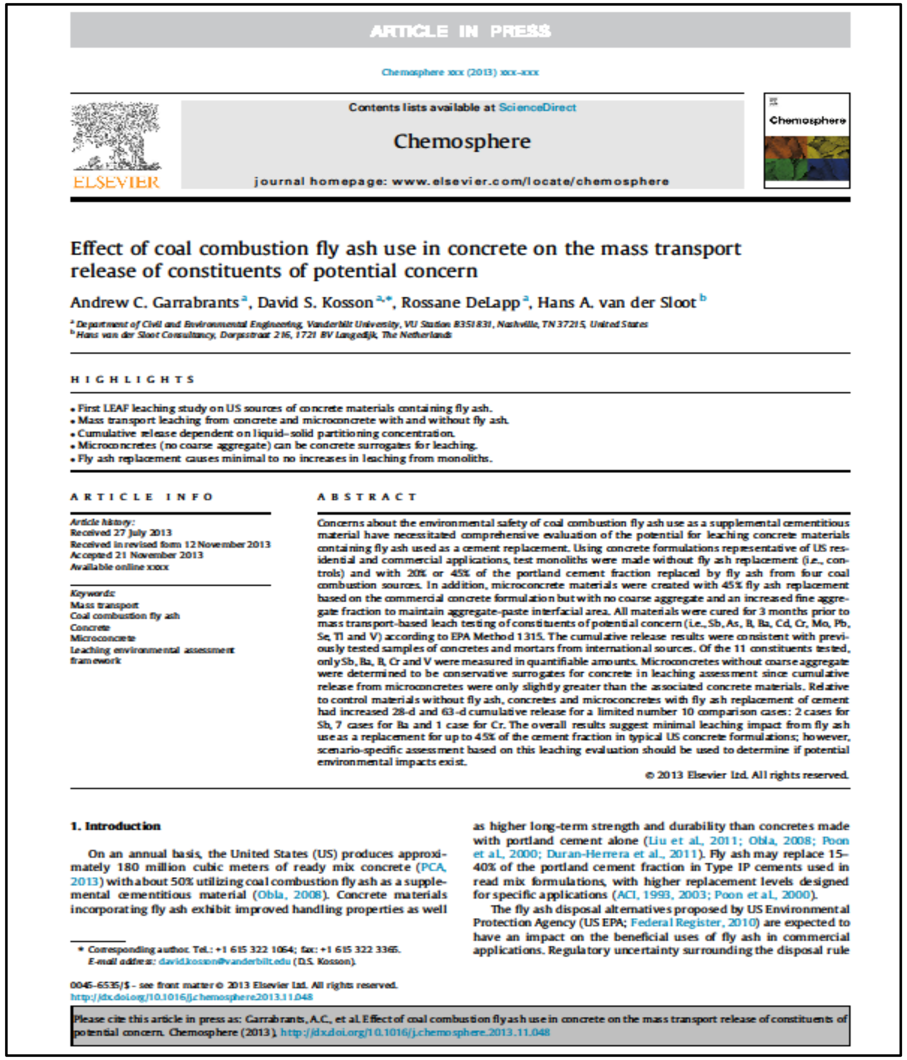
0045-6535/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.chemosphere.2013.11.049

Please cite this article in press as: Kosson, D.S., et al. pH-dependent leaching of constituents of potential concern from concrete materials containing coal combustion fly ash. Chemosphere (2013), http://dx.doi.org/10.1016/j.chemosphere.2013.11.049



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Effect of coal combustion fly ash use in concrete on the mass transport release of constituents of potential concern

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HIGHLIGHTS

- First LEAF leaching study on US sources of concrete materials containing fly ash.
- Mass transport leaching from concrete and microconcrete with and without fly ash.
- Cumulative release dependent on liquid–solid partitioning concentration.
- Microconcretes (no coarse aggregate) can be concrete surrogates for leaching.
- Fly ash replacement causes minimal to no increases in leaching from monoliths.

ARTICLE INFO

Article history:
Received 27 July 2013
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Available online xxxx

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ABSTRACT

Concerns about the environmental safety of coal combustion fly ash use as a supplemental cementitious material have necessitated comprehensive evaluation of the potential for leaching concrete materials containing fly ash used as a cement replacement. Using concrete formulations representative of US residential and commercial applications, test monoliths were made without fly ash replacement (i.e., controls) and with 20% or 45% of the portland cement fraction replaced by fly ash from four coal combustion sources. In addition, microconcrete materials were created with 45% fly ash replacement based on the commercial concrete formulation but with no coarse aggregate and an increased fine aggregate fraction to maintain aggregate-paste interfacial area. All materials were cured for 3 months prior to mass transport-based leach testing of constituents of potential concern (i.e., Sb, As, B, Ba, Cd, Cr, Mo, Pb, Se, Tl and V) according to EPA Method 1315. The cumulative release results were consistent with previously tested samples of concretes and mortars from international sources. Of the 11 constituents tested, only Sb, Ba, B, Cr and V were measured in quantifiable amounts. Microconcretes without coarse aggregate were determined to be conservative surrogates for concrete in leaching assessment since cumulative release from microconcretes were only slightly greater than the associated concrete materials. Relative to control materials without fly ash, concretes and microconcretes with fly ash replacement of cement had increased 28-d and 63-d cumulative release for a limited number 10 comparison cases: 2 cases for Sb, 7 cases for Ba and 1 case for Cr. The overall results suggest minimal leaching impact from fly ash use as a replacement for up to 45% of the cement fraction in typical US concrete formulations; however, scenario-specific assessment based on this leaching evaluation should be used to determine if potential environmental impacts exist.

1. Introduction

On an annual basis, the United States (US) produces approximately 180 million cubic meters of ready mix concrete (PCA, 2013) with about 50% utilizing coal combustion fly ash as a supplemental cementitious material (Obla, 2008). Concrete materials incorporating fly ash exhibit improved handling properties as well as higher long-term strength and durability than concretes made with portland cement alone (Liu et al., 2011; Obla, 2008; Poon et al., 2000; Duran-Herrera et al., 2011). Fly ash may replace 15–40% of the portland cement fraction in Type IP cements used in read mix formulations, with higher replacement levels designed for specific applications (ACI, 1993, 2003; Poon et al., 2000).

The fly ash disposal alternatives proposed by US Environmental Protection Agency (US EPA; Federal Register, 2010) are expected to have an impact on the beneficial uses of fly ash in commercial applications. Regulatory uncertainty surrounding the disposal rule

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Please cite this article in press as: Garrabrants, A.C., et al. Effect of coal combustion fly ash use in concrete on the mass transport release of constituents of potential concern. Chemosphere (2013), http://dx.doi.org/10.1016/j.chemosphere.2013.11.048

EXAMPLE

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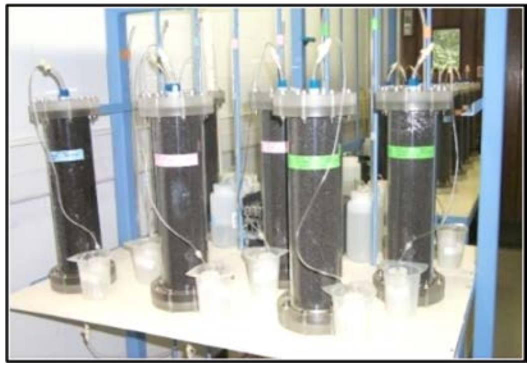
Leaching Evaluation Assessment Framework*

- **Equilibrium-based leaching tests**
  - Batch tests carried out on size reduced material
  - Aim to measure contaminant release related to specific chemical conditions (pH, LS ratio)
  - Method 1313 – pH dependence & titration curve
  - Method 1316 – LS dependence

- **Mass transport rate-based leaching tests**
  - Carried out either on monolithic or compacted granular materials
  - Aim to determine contaminant release rates by accounting for both chemical and physical properties of the material
  - Method 1315 – monolith & compacted granular options

- **Percolation (column) leaching tests**
  - May be either equilibrium or mass transfer rate
  - Method 1314 – upflow column, local equilibrium (LS ratio)



*Posted to SW-846 Validated Methods in August 2013

US EPA Reports – Methodology and Evaluation of using Coal Fly Ash and FGD Gypsum

Methodology for Evaluating Encapsulated Beneficial Uses of Coal Combustion Residuals

September 2013

Final

United States Environmental Protection Agency
Office of Solid Waste and Emergency Response
Office of Resource Conservation and Recovery

Coal Combustion Residual Beneficial Use Evaluation: Fly Ash Concrete and FGD Gypsum Wallboard

February 2014

Final

United States Environmental Protection Agency
Office of Solid Waste and Emergency Response
Office of Resource Conservation and Recovery

EXAMPLE

US EPA Reports – Methodology and Evaluation of using Coal Fly Ash and FGD Gypsum

- Methodology for Evaluating Encapsulated Beneficial Uses of Coal Combustion Residuals (September 2013)
  - Link?
- Coal Combustion Residual Beneficial Use Evaluation: Fly As Concrete and FDG Gypsum Wallboard (February 2014)
  - Link?

Leaching Environmental Assessment Framework

- LEAF is a collection of:
  - Four leaching methods
  - Data management tools
  - Geochemical speciation and mass transfer modeling
  - Quality assurance/quality control
  - Integrated leaching assessment approaches
- Designed to identify characteristic leaching behaviors for a wide range of materials and associated use and disposal scenarios.
- Integration of leaching results provides a material-specific "source term" release estimate for assessing potential groundwater impacts of land placement of materials and use in material management decisions.
- More information at http://www.vanderbilt.edu/leaching

Use of LEAF in Evaluating Beneficial Use

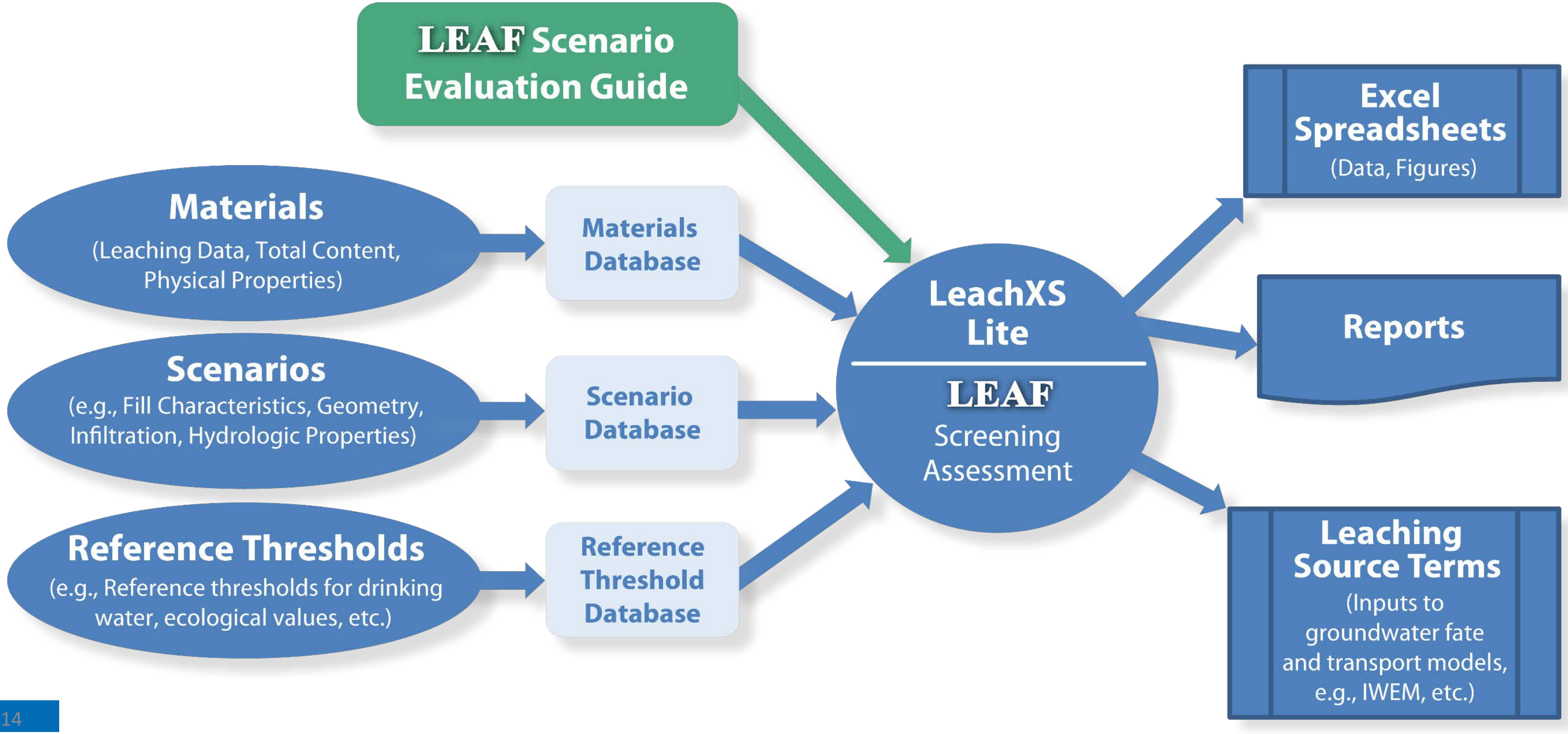
- LEAF test methods allow for:
  - Varying pH
  - Varying L/S ratio
  - Measuring monolith or granular samples
  - Up flow percolation
- Better ability to evaluate materials under conditions that they will encounter in use
- Provide standardized and tailored approach to evaluating range of materials in terms of leaching
- Provide source term needed in evaluating fate and transport (and geochemical speciation modeling for redox and other conditions not easily simulated in lab)
- ~~Soon to be released guidance: LEAF How-To Guide~~

*The LEAF methods were developed and have been validated for evaluating the leaching potential of inorganics wastes and constituents.

LEAF How-To Guide: Topics Covered

- General leaching overview
- How to proceed through the LEAF approach
- How to apply LEAF and special considerations to assess for selected management scenarios
- Case study examples that use the LEAF approach such as reuse of coal fly ash as fill material
- How to use leaching test results to model releases and inform reuse decisions
- To be released in Fall 2017 for public review

LeachXS Lite Inputs, Databases and Outputs



LEAF Data Management Tools

- LeachXS Lite software and data templates facilitate data management, evaluation, and reporting
- Data templates provided as excel spreadsheets for each method
  - Perform basic, required calculations (e.g., moisture content)
  - Record laboratory data
  - Archive analytical data with laboratory information
  - Form the upload file to materials database
- Software for LEAF data management, visualization and processing
  - Compare leaching test data
    - Between materials for a single constituent (e.g., As in two different CCRs)
    - Between constituents in a single material (e.g., Ba and SO_4 in cement)
    - To default or user-defined values indicating QA limits or health-based threshold values)
  - Export leaching data to Excel spreadsheets

Next Steps

- Public review of LEAF implementation guidance – Fall 2017
- Developing additional applications for integration into LeachXS-Lite
- Conducting updates and maintenance to software and other data management tools as needed
- Developing leach testing for organic wastes and constituents based on LEAF principles of accounting for the effects of most important factors affecting leaching
- Continued support of program office in their effort to develop guidance for evaluating industrial by-products for replacing virgin or extracted resources

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