The Leaching Environmental Assessment Framework (LEAF)

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Keywords: leaching, coal combustion residues, mercury, materials management

This paper provides an overview of newly released leaching tests that enhance estimates of the environmental release of metals and other constituents of potential concern (COPCs) be providing improved source terms. The Leaching Environmental Assessment Framework (LEAF) methods have been (1) developed for inclusion in EPA's SW-846, (2) validated working with 20 laboratories, and (3) posted on EPA's SW-846 web site as new methods. This paper provides an overview of the LEAF methods and how they can be applied.

Leaching is defined as the release of constituents from a solid material to the aqueous phase when contacted with water. Release to the aqueous phase can be determined by constituent liquid-solid partitioning (including consideration of solubility, adsorption in the solid phase, content available for leaching, aqueous complexation, etc.), the physical properties of the material that limit mass transport, the degree to which equilibrium is achieved, and the properties of the contacting liquid. The solid materials of interest may be soils or sediments (with or without known contamination), wastes (from municipal, industrial, construction, or nuclear material processing), treated wastes or waste forms (e.g., cement-stabilized wastes, vitrified wastes or products from a range of physical/chemical/thermal treatment processes), secondary materials under consideration for beneficial use (e.g., slags, flue gas desulfurization gypsum, coal fly ash), or construction materials. The contacting water may be from percolation through porous materials, flow around porous or nonporous (or fractured) monolithic materials, or from condensation processes. The material may be water-saturated or unsaturated. The source and fate of the water (and any leached constituents) may include precipitation, runoff, groundwater, surface water or collected leachate.

The goal of environmental leaching assessment is to provide an estimate of constituent leaching potential for materials under possible management scenarios that is as accurate as practical or needed, but also does not under-estimate release of COPCs. The intended use of assessments may be to evaluate the environmental safety of specific management options for a class of materials (e.g., beneficial use or disposal scenarios for coal combustion residues), evaluate a specific or set of use or disposal scenarios for a material (e.g., use of a particular coal fly ash in construction of a roadway, embankment or structural fill), establish classes or performance characteristics of materials that may be acceptable for use in defined use scenarios, compare the effectiveness of treatment processes for specific waste types (such as may be needed for regulatory determinations of equivalent treatment), delisting of materials categorized as hazardous wastes based on the material's origin, or to determine remediation goals for contaminated soils or sediments.

The constituents identified as COPCs will be specific to the material being evaluated, with specific COPCs usually considered because of their inherent human or aquatic toxicity (e.g., arsenic, mercury, etc.). However, it is important to recognize that leaching of COPCs most often is strongly influenced by the leaching of other major and trace constituents in the material being evaluated and the constituents present initially in the contacting water, the general chemical state (e.g., pH, oxidation-reduction potential, and ionic strength) of the leachant in contact with the solid, and the physical characteristics of the material that impact water contact. All of the above factors influence the LSP of COPCs and the rate and extent to which equilibrium between the solid and liquid phase is approached.

The broad range of potential uses of environmental leaching assessment implies that there is a need for a graded or tiered approach that provides for flexible, scenario-based assessments and allows tailoring of the needed testing and information based on the type of intended use of the assessment and available prior or related information. LEAF can be tailored to the range of potential environmental conditions and intrinsic leaching characteristics of materials. In parallel to U.S. research to adopt LEAF, Europe has adopted comparable methods as delineated in the table below:

U.S. EPA and Parallel European Leaching Test Methods

Parameter	LEAF Method	EU Method	EU Applications
pH-dependence	Method 1313	CEN/TS 14429 CEN/TS 14997 ISO/TS 14997	waste, mining waste, construction products waste, mining waste, construction products soil, sediments, compost, sludge
Percolation	Method 1314	CEN/TS 14405 CEN/TC351/TS-3 ISO/TS 21268-3	waste, mining waste construction products soil, sediments, compost, sludge
Mass Transport	Method 1315	CEN/TS 15683 CEN/TC351/TS-2 NEN 7347 (Dutch) NEN7348 (Dutch)	monolithic waste monolithic construction products monolithic waste granular waste and construction products,
L/S dependence	Method 1316	EN12457-2	waste

LEAF is fundamentally different than the simulation-based approach, such the toxicity characteristic leaching procedure (TCLP), because LEAF focuses on characterization of intrinsic material-specific leaching behaviors controlling the release of constituents of potential concern (COPCs) from solid materials over a broad range of test and environmental conditions, with application of the resulting leaching data to specific disposal or use conditions. The four leach testing methods described in LEAF have been validated through interlaboratory studies and adopted into SW-846:

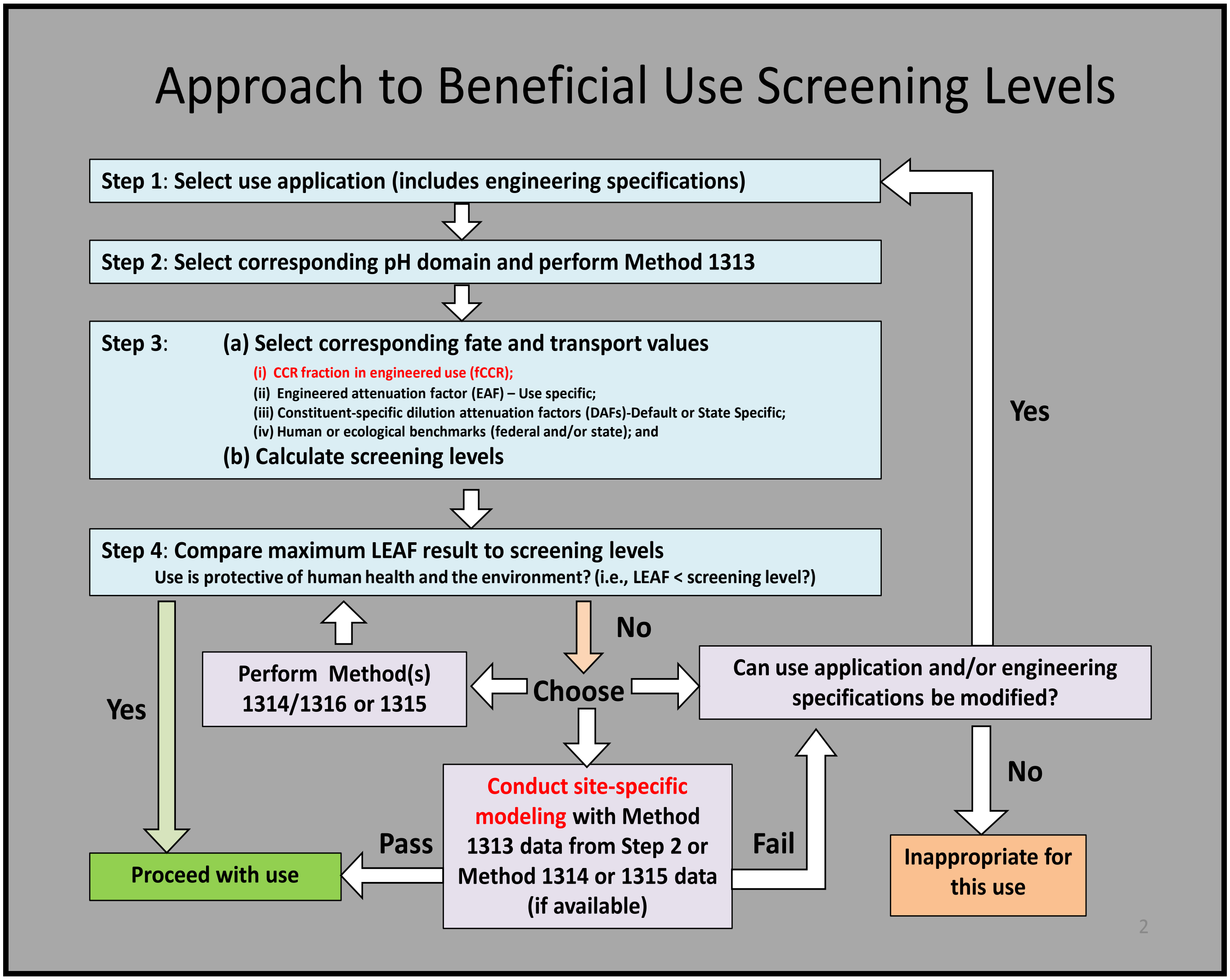
- Method 1313 – Liquid-Solid Partitioning as a Function of Extract pH using a Parallel Batch Extraction Procedure
- Method 1314 – Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio for Constituents in Solid Materials using an Up-flow Percolation Column Procedure
- Method 1315 – Mass Transfer Rates in Monolithic and Compacted Granular Materials using a Semi-Dynamic Tank Leaching Procedure
- Method 1316 – Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio in Solid Materials using a Parallel Batch Extraction Procedure

These tests may be applied to solid materials to determine fundamental leaching parameters including liquid-solid partitioning (LSP) of constituents as a function of pH and cumulative liquid-to-solid ratio (L/S) as well as the rate of constituent mass transfer from monolithic and compacted granular materials. Coordinated development of LEAF has occurred between research laboratories in the United States (U.S.) and the European Union (EU). Leaching tests are tools typically used for estimating the environmental impact associated with disposal or utilization of materials and wastes on the land (e.g., soils, sediments, industrial wastes, demolition debris, etc.). The results are used to produce inputs for fate and transport models that are inputs to risk-informed constituent concentration thresholds at defined points of compliance. Chemical speciation and reactive transport modeling provide a chemical speciation fingerprint (CSF) for the material of interest and subsequent reactive transport modeling (i.e., combination of speciation and mass transport models) explores the extent that non-ideal conditions (e.g., preferential flow) and aging conditions (e.g., redox changes, carbonation, etc.) influence observed field leaching behavior.

The resulting liquid-solid partitioning of constituents in a material at chemical equilibrium can be the result of several chemical phenomena that occur either individually, with one phenomenon dominant in the observed behavior, or with multiple phenomena occurring simultaneously with different phenomena controlling the observed behavior under different pH or L/S conditions. Evaluation of leaching data show several different response types to describe dominant leaching mechanisms under common partitioning behaviors. Most of these response types can be distinguished based on examination of the results from one or more of the LEAF test methods, however, for some situations, chemical speciation may be needed to clarify the contributing mechanisms (i.e., distinguishing between precipitation and adsorption at low constituent concentrations).

Depending upon the observed response, attenuation and dilution need to be accounted for to ensure that environmental release accounts for environmental factors as we as COPC leaching behavior. The U.S. EPA is developing a guidance document for the use of LEAF that is to include percolation and diffusion based assessments, monolith based assessment for stabilized waste and cementitious materials, and mine reclamation. The goal is once the equations, empirical data, and other information have been documented, reviewed, and approved, that the equations will be coded for use in software to make for easier LEAF implementation.

Below is a flow diagram that shows the framework for how LEAF data and source term calculations are made. Guidance is under development for wider use of LEAF in environmental management decisions reflecting differences in materials and applications.



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