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Characterizing the Leaching Behavior of Coal Combustion Residues using the Leaching Environmental Assessment Framework (LEAF) to Inform Future Management Decisions

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Abstract

Changes in emissions control at U.S. coal-fired power plants will shift metals content from the flue gas to the air pollution control (APC) residues. In order to determine the potential fate of metals that are captured through use of enhanced APC technologies, the leaching behavior of ~90 APC residues was characterized following the approach of the Leaching Environmental Assessment Framework (LEAF). Materials were tested over pH conditions and liquid-solid ratios expected during management via land disposal or beneficial use. Leachate concentrations for most metals were highly variable over a range of coal rank, facility configurations and APC residue types. Liquid-solid partitioning (equilibrium) as a function of pH showed significantly different leaching behavior for similar residue types and facility configurations. Variability in metals leaching was greater than the variability in totals concentrations by several orders of magnitude, inferring that total content is not predictive of leaching behavior. The complex leaching behavior and lack of correlation to total contents indicates that release evaluation under likely field conditions is a better descriptor of environmental performance than totals content or constant partitioning approaches. Table 1 provides a summary of the results from CCR characterization.

The U.S. EPA decided that improved leaching methods were needed and worked with over 20 laboratories in the validation of the LEAF methods for more wide-scale use in commercial and research laboratories. Historically, single point leaching tests were used; however, early in the APC residue research it was determined that this approach could be improved upon to better quantify the wide variety of CCR uses in actual field conditions. Concerns with the existing single point pH tests include lack of ability to evaluate leaching under range of conditions that CCRs are managed, ability to compare results to other CCRs and management scenarios, and the limited mechanistic understanding of how constituents of potential concern are released to the environment. Given the wide range of potential uses of CCRs including use in commercial building products, mine reclamation, highway construction, structural fills, and even toothpaste, it is particularly important to evaluate leaching under the likely environmental conditions that these materials will encounter. LEAF was

selected for use in the CCR characterization research after a rigorous scientific review (EPA Science Advisory Board and National Academy of Sciences) of available methods which were primarily single-point tests that did not reflect the range of environmental conditions that CCRs will likely be exposed to when managed. Attributes of LEAF for assessing potential environmental release include (1) its tiered approach to evaluate characteristic leaching behavior under equilibrium and dynamic conditions, (2) ability to consider a range of conditions that can be location specific and variable across the potential disposal or reuse sites (i.e., pH, infiltration rate, waste form), and (3) its flexibility to evaluate a range of materials (including CCRs) and management scenarios. The use of LEAF allows one to conduct a robust characterization of air pollution control residues as well as other materials to account for changing leaching behavior across a range of environmental conditions.

The U.S. EPA published a proposed rule on June 21, 2010 in the Federal Register, focused on CCR disposal including a discussion of beneficial uses. The final rule is expected to be completed sometime in the 2012-2013 timeframe. The U.S. EPA has been under increasing public pressure to review CCR management practices primarily due to the accidental release of approximately 4,000 million liters of coal ash sludge from a containment dike at a Tennessee power plant on December 22, 2009. The ash extended over 123 hectares of land and generated a surge of waste and ash that destroyed three homes, disrupted electrical power, ruptured a natural gas line, covered railway tracks and roadways, and necessitated the evacuation of a nearby neighborhood. About 2,300 million liters entered a nearby river and its tributaries. Proposed options include not allowing wet handling of CCRs which would prevent the use of surface impoundments at coal-fired power plants for CCR disposal.

Table 1. Range of observed total content and leaching test results ($5.4 \leq pH \leq 12.4$) for 34 fly ash samples and 20 FGD gypsum samples with initial screening concentrations.

	Indicator Values		Fly Ash		FGD Gypsum	
	TC* (µg/L)	MCL* (µg/L)	Total Content (mg/kg)	Leaching Concentration (µg/L)	Total Content (mg/kg)	Leaching Concentration (µg/L)
Mercury	200	2	0.1-1.5	<0.01-0.50	0.01-3.1	<0.01-0.66
Antimony	-	6	3-14	<0.3-**11,000**	0.14-8.2	<0.3-**330**
Arsenic	5,000	10	17-510	0.32-**18,000**	0.95-10	0.32-**1,200**
Barium	100,000	2,000	50-7,000	50-**670,000**	2.4-67	30-560
Boron	-	7,000**	NA	210-**270,000**	NA	12-**270,000**
Cadmium	1,000	5	0.3-1.8	<0.1-**320**	0.11-0.61	<0.2-**370**
Chromium	5,000	100	66-210	<0.3-**7,300**	1.2-20	<0.3-240
Molybdenum		200*	6.9-77	<0.5-**130,000**	1.1-12	0.36-**1,900**
Selenium	1,000	50	1.1-210	5.7-**29,000**	2.3-46	3.6-**16,000**
Thallium	-	2	0.72-13	<0.3-**790**	0.24-2.3	<0.3-**1,100**

*TC = toxicity characteristic, MCL =Maximum concentration limit for drinking waste.
**Indicates DWEL value rather than MCL. Bold text indicates where leaching concentrations are greater than indicator values. Indicator values shown for comparison to leaching test concentration as an initial screening only (leaching results do not include dilution/attenuation considered in development of indicator values).

CCRs are considered a high volume waste in the U.S. with 123 million tonnes produced as of 2009. Since 2001, utilization of CCRs has grown from 32% to 44% as of 2008 (33 to 54 million tonnes). In some instances, CCRs appear to work better than the materials they replace, such as longer life of some concrete building products. However, better characterization of potential leaching behavior – particularly in light of changes to CCRs in response to APC changes – is needed to ensure protection of human health and the environment.

In parallel to the U.S. EPA effort, Europe has developed comparable methods. Europe recently decided they will use the validation data generated from the recent U.S. research instead of repeating the work that was done. As a result, Europe and the U.S. will be able to readily share data in the future that is comparable across a range of materials and management scenarios. Use of secondary materials – while ensuring protection of human health and the environment – can help lead towards more sustainable solutions that conserve energy and natural resources.

References

American Coal Ash Association. 2010 Coal Combustion Product Production and Use Statistics. Available at http://www.adaa.asn.au/documents/ADAA_Mship_Report_2010.pdf (accessed August 2012).

Electric Power Research Institute. Impact of Air Emissions Controls on Coal Combustion Products; EPRI 1015544; EPRI: Palo Alto, CA, 2008.

Andrew C. Garrabrants, Kosson, D. S.; Sloot, H. A. v. d.; Sanchez, F.;A.; Kosson[1], Hans A. van der Sloot[2], Sanchez, F.; Hjelmar, O. Background Information for the LEAF Test Methods, EPA/600/R-10/170, Dec 2010.

Kilgroe, J.; Sedman, C.; Srivastava, R.; Ryan, J.; Lee, C. W.; Thorneloe, S. Control of Mercury Emissions from Coal-Fired Electric Utility Boilers: Interim Report; EPA-600/R-01-109; EPA Office of Research and Development, National Risk Management and Research Laboratory: Research Triangle Park, NC, December, 2001.

Kosson, D. S.; Sanchez, F.; Kariher, P.; Turner, L. H.; Delapp, R.; Seignette, P. Characterization of Coal Combustion Residues from Electric Utilities – Leaching and

Characterization Data; EPA-600/R-09/151; EPA Office of Research and Division, National Risk Management and Research Laboratory: Research Triangle Park, NC, December, 2009.

Leaching Environmental Assessment Framework (LEAF). Available at http://www.vanderbilt.edu/leaching/LEAF.html (accessed July 2012).

Sanchez, F.; Keeney, R.; Kosson, D. S.; Delapp, R. Characterization of Mercury-Enriched Coal Combustion Residues from Electric Utilities Using Enhanced Sorbents for Mercury Control; EPA-600/R-06/008; EPA Office of Research and Division, National Risk Management and Research Laboratory: Research Triangle Park, NC, February 2006, 2006.

Sanchez, F.; Kosson, D. S.; Keeney, R.; Delapp, R.; Turner, L.; Kariher, P.; Thorneloe, S. Characterization of Coal Combustion Residues from Electric Utilities Using Wet Scrubbers for Multi-Pollutant Control; EPA-600/R-08/077; EPA Office of Research and Development, National Risk Management and Research Laboratory: Research Triangle Park, NC, July, 2008.

Thorneloe, S.; Kosson, D. S.; Helms, G.; Garrabrants, A. C., Improved Leaching Test Methods for Environmental Assessment of Coal Ash and Recycled Materials Used in Construction. In Proceedings of the International Waste Management & Landfill Symposium, S. Margherita di Pula, Cagliari, Italy, 2009.

Thorneloe, S.; Kosson, D.; Sanchex, F.; Garrabrants, A.; Helms, G. Evaluating the Fate of Metals in Air Pollution Control Residues from Coal-Fired Power Plants, Environ. Sci. Technol. 2010, 44, 7351-7356.