Materials Characterization Paper
In Support of the
Advanced Notice of Proposed Rulemaking –
Identification of Nonhazardous Materials That Are Solid Waste

Cement Kiln Dust (CKD)

December 16, 2008

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1. Definition of CKD

Cement kiln dust (CKD) is a fine-grained, solid, highly alkaline material removed from the cement kiln exhaust gas by scrubbers (filtration baghouses and /or electrostatic precipitators). The composition of CKD varies among plants and over time at a single plant. Much of the material comprising CKD is incompletely reacted raw material, including a raw mix at various stages of burning, and particles of clinker.

2. Annual Quantities of CKD Generated and Used

(1) **Sectors that generate CKD:**

- CKD is generated by NAICS industry sector 327310, Cement Manufacturing (U.S. Census Bureau, 2002). This sector included 247 facilities in 2002 according to the U.S. Census of Manufacturers. EPA reports that this sector included 144 facilities in 2006 (EPA 2006).

(2) **Quantities of CKD generated:**

- An estimated 13 to 17 million short tons of CKD are generated per year (EPA 2008).[1]

(3) **Trends in generation of CKD:**

- Generation of CKD is directly connected to the production of cement clinker (the initial product of a cement kiln before processing). Significant increases in U.S. clinker capacity are expected to materialize during 2008 to 2012, anticipating an increase in production. The U.S. cement industry has announced plans to increase clinker capacity by nearly 25 million metric tons between 2007 and 2012. The capacity expansion reflects a $5.9 billion investment, which will increase capacity 27 percent compared to 2006 U.S. clinker capacity (Cement Americas 2008). Assuming that capacity utilization is constant, a CKD production increase of 27 percent is also anticipated.
- The U.S. cement industry has adopted a year 2020 voluntary target of a 60 percent reduction (from a 1990 baseline) in the amount of cement kiln dust disposed per

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[1] Because of the high rate of direct reuse, CKD generation rates are not routinely measured, and limited data are available. U.S. cement kiln industry personnel estimate that CKD generation (including material returned to the kiln) is equivalent to approximately 15% to 20% (by weight) of total annual clinker production (EPA 2008).

ton of clinker produced (EPA 2007). Through CKD reduction efforts by Portland Cement Association (PCA) member companies, this goal was accomplished in 2004. The PCA is currently developing a new CKD reduction goal (IEEE-IAS 2008).

3. Uses of CKD

(1) **Ingredient uses of CKD:**

- Because of the high percentage of raw mix and clinker in CKD, CKD can be directly reused in the cement kiln for clinker manufacture (EPA 2008). The cement industry recycles more than 75 percent of its CKD, nearly eight million tons each year (EPA 2006).
- CKD partially substitutes for virgin raw materials in kiln feed. Kiln feed is generally comprised of about 80 percent carbonate of lime and about 20 percent silica with much lower quantities of alumina and iron. Limestone is the primary source of calcium for nearly all cement plants. Shale, clay, and sand are the primary materials fed as sources of silica and alumina (EPA 1995). CKD can substitute for any or all of these materials, depending on the composition of the clinker from which it was generated.

(2) **Non-combustion uses of CKD:**

- CKD not returned to the production process can be sold for various types of commercial applications, including agricultural soil enhancement, base stabilizing for pavements, wastewater treatment, waste remediation, low-strength backfill and municipal landfill cover. These applications depend primarily on the chemical and physical characteristics of the CKD. The major parameters that determine CKD characteristics are the raw feed material, type of kiln operation, dust collection systems, and fuel type. Since the properties of CKD can be significantly affected by the design, operation and materials used in a cement kiln, the chemical and physical characteristics of CKD must be evaluated on an individual plant basis (IEEE-IAS 2008).

(3) **Quantities of CKD landfilled:**

- The majority of CKD is recycled directly back to the cement kiln, thus avoiding disposal; however, CKD must periodically be removed from the system due to increasing concentrations of various contaminants that may compromise the quality of the clinker. The Portland Cement Association estimates that 6.4 million tons of CKD were landfilled in 2003 (EPA 2006).

(4) **Quantities of CKD stockpiled/stored:**

- CKD that cannot be recycled back into the cement kiln (because of excessive alkali content, as well as other operational factors) is removed from the system and often collected onsite in piles or monofills (EPA 1995). Current estimates of the stockpiled quantity of CKD are not available, however.
- A recent trend at some cement manufacturing facilities is the removal or "mining" of CKD placed in landfills or other long-term management units. From the PCA

CKD surveys of member companies, it was estimated that the amount of CKD removed from onsite landfills has grown from just over 13,400 metric tons in 1998 to more than 261,000 metric tons in 2006. Because CKD is very similar to the raw materials entering the kiln system and may contain partially processed feed or final product, it requires less processing prior to use in the kiln and thus, less energy. Consequently, CKD is becoming more valuable as manufacturing costs rise (IEEE-IAS 2008).

Exhibit 1: Overview of Generation and Use of CKD in 2004

Commodity	**Annual Quantity Generated**	**Annual Quantity Used as Ingredient**		**Annual Quantity Landfilled**	**Annual Quantity in Other Uses**	**Total Quantity Stockpiled**
		Cement Kilns	**Other**			
	-------------------------------- *Short Tons* ------------------------------					
Cement kiln dust	13.23–16.53 million	0.36 million[a]	0	6.4 million	1.23 million	Not Available

Sources:
Unless otherwise noted, data is from U.S. EPA, *Study on Increasing the Usage of Recovered Mineral Components in Federally Funded Projects Involving Procurement of Cement or Concrete to Address the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users*, April 28, 2008.
Notes:
Based on PCA data and discussions with industry personnel, actual rate of reuse in cement kilns appears to be underreported. Subsequently, the estimated quantity landfilled is likely overstated.

4. Management and Combustion processes for CKD

(1) **Types of units using CKD:**

- Cement kiln dust is returned to cement kilns during the clinker manufacturing process.

(2) **Sourcing of CKD:**

- A closed-loop process captures CKD from exhaust gas scrubbers at cement plants and returns it directly to the kiln.

(3) **Processing of CKD:**

- CKD captured from kiln exhaust gasses is directly reinjected back into the kiln, and does not require processing. CKD mined from stockpiles may require processing prior to injection into the cement kiln.[2]

(4) **State status of CKD use as ingredient:**

- According to state responses to a 2006 survey by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), Florida and Iowa

[2] The sources consulted for this document do not provide detailed information on the actual processing steps.

have pre-approved the use of CKD in the production of cement as a beneficial use, exempting it from the case-by-case approval process for designation of beneficial use (ASTSWMO 2007, p.B-9).

5. CKD Composition and Impacts

(1) **Composition of CKD:**

- CKD is comprised of thermally unchanged raw materials, dehydrated clay, decarbonated (calcined) limestone, ash from fuel, and newly formed minerals corresponding to all stages of processing up through the formation of the clinker. An unusual feature of CKD is that, unlike typical by-product materials that are substantially different than the product, CKD is essentially cement clinker that does not quite meet commercial specifications (EPA 1995).
- The primary constituents in CKD are silicates, calcium oxide, carbonates (expressed as loss of CO2 and H2O on ignition), potassium oxide, sulfates, chlorides, various metal oxides, and sodium oxide (EPA 1995).
- CKD contains insignificant amounts of trace metals and therefore metal concentrations are not usually a concern for most applications. A comprehensive study by the Portland Cement Association evaluated the presence of trace metals in CKD from 79 plants in the United States and 10 plants in Canada using both conventional and other fuels. Each CKD sample was tested for the eight RCRA metals: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The samples were also analyzed for antimony, beryllium, thallium and nickel. Results showed that the average level of trace metals found in the CKD were significantly below the regulation limits (IEEE-IAS 2008).
- The predominant trace metals in CKD include antimony, barium, lead, manganese, strontium, thallium, and zinc, and the minor trace metals include beryllium, copper, hexavalent chromium, mercury, nickel, silver, and thallium (EPA 1995). The concentration of these metals in CKD varies significantly by cement plant depending on the mix of raw feed materials used in clinker production and the type of fuel used in the cement kiln (May 1999).

(2) **Impacts of CKD use:**

- In clinker manufacture, CKD partially offsets the need for virgin material feed, such as limestone and natural constituents (rock). Thus, returning CKD to the cement kiln can reduce the unit consumption of virgin feed stock in the kiln, which may then reduce the costs of raw materials and emissions from extraction and processing of virgin materials, as CKD requires less processing (and thus less energy) for use in cement than virgin raw materials. However, using CKD in place of virgin materials may change the emissions from the kiln to the extent CKD has a different emissions profile than the alternative virgin materials when burned in the kiln.
- Some of the metal constituents in CKD (e.g., mercury and lead) may be volatilized when the material is heated to high temperatures in the cement kiln.
- The specific lifecycle impacts of CKD use as a raw material in clinker production are not evaluated here because of uncertainties in lifecycle scenario development.

For example, it is difficult to determine the replacement ratio between CKD and other raw feed materials in clinker production. Thus, the correct quantity of material to be modeled is unclear. In addition, CKD may substitute for a variety of virgin raw materials as well as other secondary materials (e.g., blast furnace slag, CCPs, foundry sand, etc.); the choice of material often depends on location-specific factors such as the proximity of material sources to the cement kiln and relative availability of different materials. Avoided upstream impacts depend heavily on the specific material being displaced in the lifecycle scenario.

References

Association of State and Territorial Solid Waste Management Officials (ASTSWMO). 2007, *2006 Beneficial Use Study Report*, published by Association of State and Territorial Solid Waste Management Officials, November 2007.

Cement Americas, January 1, 2008, *Cement Americas Forecast 2008*, accessed at: http://cementamericas.com/mag/cement_forecast_0101/index.html.

IEEE-Industry Applications Society (IEEE-IAS). 2008, *Beneficial Uses of Cement Kiln Dust,* presented at the 2008 IEEE/PCA 50th Cement Industry Technical Conference., Miami, FL, May 19-22, 2008

May, Mallory. May 1, 1999, *A Study on Trace Metals in Portland Cement Kiln Dust*, accessed at: http://cementamericas.com/mag/cement_study_trace_metals/.

United States Census Bureau, 2002 Economic Census*, Industry Snapshots for Cement Manufacturing*, accessed on August 18, 2008 at: http://quarterhorse.dsd.census.gov/TheDataWeb_HotReport/servlet/HotReportEngineServlet?emailname=bh@boc&filename=mfg1.hrml&20071204152004.Var.NAICS2002=327310&forward=20071204152004.Var.NAICS2002.

United States Environmental Protection Agency (EPA). 1995, *Report to Congress on Cement Kiln Dust*, accessed at: http://www.epa.gov/epaoswer/other/ckd/cement2.htm.

United States Environmental Protection Agency (EPA). 2006, *Sector Strategies Performance Report: Cement*, accessed at: http://www.epa.gov/ispd/pdf/2006/cement.pdf.

United States Environmental Protection Agency (EPA). March 2007, *Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes*, accessed at: http://www.epa.gov/ispd/pdf/energy/report.pdf.

United States Environmental Protection Agency (EPA). April 28, 2008, *Study on Increasing the Usage of Recovered Mineral Components in Federally Funded Projects Involving Procurement of Cement or Concrete to Address the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users*.