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

Silica Fume - Used as ingredient in clinker manufacture

December 16, 2008

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1. Definition of Silica Fume

Silica fume is a fine, dust-like material generated during silicon metal and ferrosilicon and related ferroalloys (e.g., stainless steel) production. Specifically, it is produced by the reduction of high purity quartz with coal or coke and wood chips in an electric arc furnace during silicon metal or ferrosilicon alloys production. The glassy, spherical particles are extremely small, measuring less than one micrometer (μm) in diameter, with an average diameter of about 0.1 μm. Silica fume particles are composed primarily of silicon dioxide (usually more than 85 percent).

2. Annual Quantities Generated and Used

(1) **Sectors that generate silica fume:**

- Silica fume is generated by NAICS sector 331112, Electrometallurgical Ferroalloy Product Manufacturing. This includes facilities that manufacture stainless steel and cast iron.

(2) **Quantities and prices of silica fume generated:**

- The Silica Fume Association estimates that silica fume production in the United States in 2004 was between 110,000 and 132,000 short tons.
- In 2006, one major silica fume supplier reported the bulk price of silica fume, freight on board (FOB) (i.e., not including shipping costs), at $205/ton. It is unclear if this is representative of the price of silica fume from other suppliers.

(3) **Trends in generation of silica fume:**

- Growing U.S. customer needs for alloy and stainless steel is expected to continue to have a strong positive influence on ferroalloy demand (USGS 2006). As a result, production of ferroalloys and of silica fume as a byproduct are likely to remain constant or increase in the next several years.

3. Uses of Material/Commodity

(1) **Ingredient uses of silica fume:**

- Silica fume can be used in clinker manufacture as a partial replacement for silica-containing raw materials (e.g., clay, shale, sand, and limestone). Because of the high price of this material, however, and the relative abundance of other secondary materials and virgin materials, use of silica fume as a raw material for clinker is less common, though it still occurs (Guerra 2008). In 2004, 20,000 tons of silica fume were used in cement kilns (EPA 2008).
- Cement kilns are represented by NAICS industry sector 327310, Cement Manufacturing, which included 247 facilities in 2002 (U.S. Census Bureau 2002).

(2) **Non-combustion uses of silica fume:**

- Silica fume can be also be used at cement plants as a supplementary cementitious material (i.e., after the production of clinker in the kiln) either by premixing silica fume with finished portland cement to produce a blended cement (during the cement production process) or by adding the silica fume to portland cement concrete as a mineral admixture. In addition, silica fume is frequently used in consumer products such as toothpaste (Guerra 2008). Use of silica fume in non-combustion uses in 2004 totaled approximately 70,000 tons (EPA 2008).

(3) **Quantities of silica fume landfilled:**

- The Silica Fume Association estimates that about 28,000 short tons of silica fume were landfilled in 2004 (EPA 2008). Given the commodity value of silica fume, it is not clear why any is landfilled; possible reasons include contamination of the silica fume or lack of market access due to location of the furnaces.

(4) **Quantities of silica fume stockpiled/stored:**

- Data regarding stockpiling or storage of silica fume are not readily available, but demand for the material and the relatively modest quantities produced suggest that little, if any, silica fume is collected for long-term storage.

Exhibit 1: Overview of Generation and Use of Silica Fume 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					
Silica fume	0.11-0.13 million	0.02 million	0	0.03 million	0.07 million	Undetermined; not likely to be significant

Sources:
Unless otherwise noted, data is from U.S. 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*.

4. Management and Combustion processes

(1) **Types of combustion units using silica fume:**

- Silica fume is used in cement kilns during the clinker manufacture process.

(2) **Sourcing of silica fume:**

- Silica fume is marketed by a variety of admixture suppliers in the U.S. who obtain the material from the generators and prepare it for resale. There are five domestic silica fume producers listed in the Silica Fume Association, all of whom are located in the Southeastern United States. The product is typically sold packaged in 25 pound bags and in bulk (Robl and Groppo 2007).

(3) **Processing of silica fume:**

- Prior to use as a supplementary cementitious material, silica fume may be densified by tumbling the material in a silo, which causes surface charges to build up. The charges draw the particles together to form weak agglomerates. Because of the increased bulk density, the material is more economical for truck transport (Silica Fume Association 2005).

(4) **State status of silica fume use as ingredient:**

- At this stage, we have not identified any states that have specifically granted beneficial use designation to the use of silica fume in clinker manufacture, or that prohibit use of silica fume in clinker, but we have not performed an exhaustive investigation of state activities and regulations.

5. Commodity Composition and Impacts

(1) **Composition of silica fume:**

- Silica fume consists of 85 percent amorphous (non-crystalline) silicon dioxide (SiO2). There may be additional materials in silica fume depending on the metal being produced in the smelter from which the silica fume was collected (Silica Fume Association 2005).

(2) **Impacts of silica fume use as ingredient:**

- If used in clinker manufacture, silica fume partially offsets natural sources of silica, such as clay, shale, sand, and limestone. Thus, using silica fume in the cement kiln would avoid the energy use and environmental releases associated with the extraction and processing of these virgin materials.
- The specific lifecycle impacts of silica fume use as a raw material in clinker production are not evaluated here because it appears silica fume has limited use in this application, and because of uncertainties in lifecycle scenario development. For example, it is difficult to determine the replacement ratio between silica fume and other raw feed materials in clinker production. Thus, the correct quantity of material to be modeled is unclear. In addition, silica fume may substitute for a variety of virgin raw materials, as well as other secondary materials (e.g., blast furnace slag, CCPs, foundry sand, cement kiln dust, 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

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