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Project Summary

Lime and Cement Industry Particulate Emissions: Source Category Report, Volume II. Cement Industry

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The objective of this study was to develop particulate emission factors based on cutoff size for inhalable particles for the cement industry. After a review of available information characterizing particulate emissions from cement plants, the data were summarized and rated in terms of reliability. Size specific emission factors were developed from these data for the major processes used in the manufacture of cement. A detailed process description was presented with emphasis on factors affecting the generation of emissions. A replacement for Section 8.6 (Portland Cement Manufacturing) of EPA report AP-42, A Compilation of Air Pollutant Emissions Factors, was prepared, containing the size specific emission factors developed during this program.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The purpose of this program was to summarize the best available information on emissions of inhalable particulate matter in the cement industry. The main objective of the program was to develop reliable size-specific emission factors for the various processes used in the production of cement. Both uncontrolled and controlled emission factors are presented in the report. The uncontrolled factors represent emissions which would result if the particulate control device (baghouse, ESP, etc.) were bypassed, and the controlled factors represent emissions emanating from a particular type of control system. The size-specific emission factors are generally based on the results of simultaneous sampling at the inlet and outlet of the control device(s), utilizing a variety of particle sizing techniques. Other objectives of this program were to present current information on the cement industry as well as prepare a replacement for Section 8.6 in EPA report AP-42, "A Compilation of Air Pollutant Emissions Factors."

The above objectives were met by a thorough literature search which included:

- Data from the inhalable particulate characterization program.
- Fine Particle Emissions Inventory System (FPEIS).
- AP-42 background file at EPA's Office of Air Quality Planning and Standards (OAQPS).
- State and local air pollution control agencies.
- Various industry sources (e.g., Portland Cement Association).

The emission data contained in the reference documents were reviewed, analyzed, summarized, and ranked according to the criteria established by OAQPS as published in the EPA report, "Technical Procedures for Developing

AP-42 Emission Factors and Preparing AP-42 Sections," April 1980. After ranking the data, emission factors were calculated using the highest quality data available. The quality of the data used to develop each emission factor is indicated by the emission factor rating.

Process control system operating data as well as general industry information were also obtained and summarized as general background information. It was not part of this program to provide detailed engineering analyses, product specifications, or a detailed evaluation of trends in the industry.

Summary of Results

Portland cement manufacture accounts for about 98% of the cement production in the U.S. The more than 30 raw materials used to make cement may be divided into four basic components: lime (calcareous), silica (siliceous), alumina (argillaceous), and iron (ferriferous).

In the dry process, the moisture content of the raw material is reduced to less than 1%, either before or during the grinding operation. The dried materials are then pulverized and fed directly into a rotary kiln. The material is dried, decarbonated, and calcined as it travels through the heated kiln and finally burns to incipient fusion and forms the clinker. The clinker is cooled, mixed with about 5% gypsum by weight, and ground to the final fineness. The product, cement, is then stored for later packaging and shipment.

In the wet process, a slurry is made by adding water to the initial grinding operation. Proportioning may take place before or after the grinding step. After the materials are mixed, the excess water is removed and final adjustments are made for the desired composition. This final homogeneous mixture is fed to the kilns as a slurry (30-40% moisture) or as a wet filtrate (about 20% moisture). The burning, cooling, addition of gypsum, and storage are then carried out as in the dry process.

Particulate matter is the primary emission in the manufacture of Portland cement. Emissions also include the normal combustion products of the fuel used for heat in the kiln and drying operations, including nitrogen oxides and small amounts of sulfur oxides.

Dust sources at cement plants are: (1) quarrying and crushing, (2) raw material storage, (3) grinding and blending (dry process only), (4) clinker production and cooling, (5) finish grinding, and (6) packaging. The largest single point of emissions is the kiln, which may be considered to have three units: the feed system, the fuel firing system, and the clinker cooling and handling system. Additional sources of dust are quarrying, raw material and clinker storage piles, conveyors, storage silos, loading/unloading facilities, and paved/unpaved roads.

Depending upon the emission, the temperature of the effluents in the plant in question, and the particulate emission standards in the area, the cement industry generally uses mechanical collectors, electrostatic precipitators, fabric filters, or combinations of these to control emissions.

The total mass uncontrolled emission factors for cement manufacturing are presented in Table 1, and controlled emission factors are presented in Table 2. Size-specific emission factors for cement kilns are presented in Table 3, and for cement clinker coolers, in Table 4.

Table 1. *Uncontrolled Emission Factors for Cement Manufacturing*[a]

Emission Factor Rating: E

			Sulfur dioxide[c]											
	Particulate[b]		*Mineral source*[d]		*Gas combustion*		*Oil combustion*		*Coal combustion*		*Nitrogen oxides*		*Lead*	
Process	*kg/Mg*	*lb/ton*	*kg/Mg*	*lb/ton*	*kg/Mg*	*lb/ton*	*kg/Mg*	*lb/ton*	*kg/Mg*	*lb/ton*	*kg/Mg*	*lb/ton*	*kg/Mg*	*lb/ton*
Dry process kiln	128	256	5.4	10.8	Neg	Neg	2.2S	4.4S	3.6S	7.2S	1.4	2.8	0.06	0.12
Wet process kiln	120	240	5.4	10.8	Neg	Neg	2.2S	4.4S	3.6S	7.2S	1.4	2.8	0.05	0.10
Clinker cooler[e]	4.6	9.2	—	—	—	—	—	—	—	—	—	—	—	—
Dryers, grinders, etc.[f]														
Wet process	16.0	32.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01	0.02
Dry process	48.0	96.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.02	0.04

[a] *Units of clinker produced, assuming 5% gypsum in finished cement. Includes fuel combustion emissions, which should not be calculated separately. Neg = negligible. S = % sulfur in fuel. Dash = no data. NA = not applicable.*

[b] *Emission Factor Rating: B*

[c] *Factors account for reactions with alkaline dust, with no controls. One test series for gas- and oil-fired wet process kilns, with limited data, suggests that 21-45% of SO_2 can be removed by reactions with the alkaline filter cake, if baghouses are used.*

[d] *From sulfur in raw materials, which varies with their sources. Factors account for some residual sulfur, because of its alkalinity and affinity for SO_2.*

[e] *Emission Factor Rating: D.*

[f] *Units of cement produced.*

Table 2. Controlled Particulate Emission Factors for Cement Manufacturing[a]

Type of source	Control technology	Particulate kg/Mg clinker	Particulate lb/ton clinker	Emission factor rating
Wet process kiln	Baghouse	0.57	1.1	C
	ESP	0.39	0.78	C
Dry process kiln	Multiclone	130[b]	260[b]	D
	Multiclone + ESP	0.34	0.68	C
	Baghouse	0.16	0.32	B
Clinker cooler	Gravel bed filter	0.16	0.32	C
	ESP	0.048	0.096	D
	Baghouse	0.010	0.020	C
Primary limestone crusher[c]	Baghouse	0.00051	0.0010	D
Primary limestone screen[c]	Baghouse	0.00011	0.00022	D
Secondary limestone screen and crusher[c]	Baghouse	0.00016	0.00032	D
Conveyor transfer[c]	Baghouse	0.000020	0.000040	D
Raw mill system[c,d]	Baghouse	0.034	0.068	D
Finish mill system[e]	Baghouse	0.017	0.034	C

[a] Units of kg particulate/Mg (lb particulate/ton) of clinker produced, except as noted. ESP = electrostatic precipitator.
[b] Based on a single test of a dry process kiln fired with a combination of coke and natural gas. Not generally applicable to a broad cross section of the cement industry.
[c] Units of mass of pollutant/mass of raw material processed.
[d] Includes mill, air separator, and weigh feeder.
[e] Includes mill, air separator(s), and one or more material transfer operations. Units of cement produced.

Table 3. Size Specific Particulate Emission Factors for Cement Kilns[a]

Emission Factor Rating: D

Particle size (μm)	Cumulative mass % < stated size[b]						Cumulative emission factor < stated size[c]											
	Uncontrolled				Baghouse		Uncontrolled				Dry process with multiclone[d]		Wet process with ESP		Baghouse			
	Wet process kiln	Dry process kiln	Dry process kiln with multiclone[d]	Wet process kiln with ESP	Wet process kiln	Dry process kiln	Wet process		Dry process						Wet process		Dry process	
							kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
2.5	7.0	18	3.8	64	NA	45	8.4	17	23	46	5.0	10	0.25	0.50	NA	NA	0.073	0.15
5.0	20	NA	14	83	NA	77	24	48	—	—	19	38	0.32	0.64	NA	NA	0.13	0.26
10.0	24	42	24	85	NA	84	29	58	54	108	32	64	0.33	0.66	NA	NA	0.14	0.28
15.0	35	44	31	91	NA	89	43	86	57	114	41	82	0.36	0.72	NA	NA	0.15	0.30
20.0	57	NA	38	98	NA	100	68	136	—	—	49	98	0.39	0.78	NA	NA	0.16	0.32
Total mass emission factor							120	240	128	256	130	260	0.39	0.78	0.57	1.1	0.16	0.32

[a] ESP = electrostatic precipitator. NA = not available. Dash = no data.
[b] Aerodynamic diameter. Percentages rounded to two significant figures.
[c] Units of weight of particulate/unit weight of clinker produced, assuming 5% gypsum in finished cement. Rounded to two significant figures.
[d] Based on a single test, and should be used with caution.

Table 4. *Size Specific Emission Factors for Clinker Coolers*

Emission Factor Rating: E

Particle size[a] (μm)	Cumulative mass % < stated size[b]		Cumulative emission factor < stated size[c]			
			Uncontrolled		Gravel bed filter	
	Uncontrolled	Gravel bed filter	kg/Mg	lb/ton	kg/Mg	lb/ton
2.5	0.54	40	0.025	0.050	0.064	0.13
5.0	1.5	64	0.067	0.13	0.10	0.20
10.0	8.6	76	0.40	0.80	0.12	0.24
15.0	21	84	0.99	2.0	0.13	0.26
20.0	34	89	1.6	3.2	0.14	0.28
Total mass emission factor			4.6	9.2	0.16	0.32

[a]Aerodynamic diameter.
[b]Rounded to two significant figures.
[c]Unit weight of pollutant/unit weight of clinker produced. Rounded to two significant figures.

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The complete report, entitled "Lime and Cement Industry Particulate Emissions: Source Category Report, Volume II. Cement Industry," (Order No. PB 87-168 654/AS; Cost: $36.95, subject to change) will be available only from:
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