



Project Summary

Cost of Controlling Directly Emitted Acidic Emissions from Major Industrial Sources

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Stationary U.S. sources, each of which as a group emits over 4,500 Mg (5000 tons) or more of acidic material (e.g., acid sulfates, HCl, HF) per year, include: utility and industrial boilers, Claus sulfur recovery plants, catalytic cracking units, primary copper smelters, coke oven plants, primary aluminum smelters, and municipal solid waste incinerators. Utility and industrial boilers are by far the largest sources, emitting about 760,000 Mg (830,000 tons) and 180,000-250,000 Mg (200,000-275,000 tons) of acidic material per year, respectively. Using a model plant approach, estimates were made of costs for retrofitting selected control systems to these plants. Cost-effectiveness (defined as the unit annual cost for removal of the acidic materials) of each control system was calculated based on the anticipated performance of the system. If SO₂ is simultaneously emitted with the acidic materials, controls were selected which removed both SO₂ and the acidic materials. Cost-effectiveness was considerably better for the combined (SO₂ + acidic material) removal systems. For example, a limestone wet scrubber on a 600 MW, high-sulfur-coal-fired utility boiler was estimated to have a cost-effectiveness of \$65,000/Mg (\$59,000/ton) for acid sulfates, HCl, and HF, but a combined (SO₂ + acidic material) cost effectiveness of \$1100/Mg (\$1000/ton). Because of a need for performance data on acidic emissions control systems, it would be desirable if research could be conducted on removal of acid sulfates and nitrates by existing gaseous and particulate control systems.

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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 Acid Precipitation Act of 1980 established an Interagency Task Force to develop a comprehensive research program for investigation of acid precipitation issues. The National Acid Precipitation Assessment Program (NAPAP) was subsequently established to develop the necessary data and provide a framework for policy recommendations in regard to acid precipitation. One aspect of the overall acid deposition issue is to understand the role and significance of direct emissions of acidic materials. As such, it is necessary to identify the major industrial sources of direct emissions of acidic material (e.g., sulfates, chlorides) and to evaluate the control of these materials. In addition, it is important to know if the most cost-effective methods for reducing acidic emissions differ from those for controlling acid deposition precursors (SO₂, NO_x, and VOC).

Accordingly, the objectives of this study were: 1) to identify and characterize stationary combustion and industrial sources of directly emitted acidic materials in the U.S.; 2) to evaluate the technical feasibility of control techniques for these sources; and 3) to estimate the costs of applying these control technologies. This assessment was conducted by reviewing and analyzing existing data, including the preliminary control strategies evaluated by the Interagency Task Force. The potential for emissions from transportation sources was not examined in this study.

Results of the study can be used to evaluate the merits of controlling directly emitted acidic materials as part of a policy evaluation of overall acid deposition control strategies. For example, if it were determined that (for a region) local emissions of directly emitted acid materials were more significant than long range precursor emitters, the information in this report could be used to evaluate the cost-effectiveness of controlling local sources of directly emitted acidic materials versus sources of long range precursor emissions.

Methodology

To identify and characterize sources of directly emitted acidic materials, national acidic materials emissions of all stationary combustion and industrial sources were identified by means of a literature search. Model units were then developed for sources that emit 4,500 Mg (5,000 tons) or more of acidic material per year. The model units were used as bases for establishing control techniques and for determining the technical feasibility of candidate conventional control techniques. The cost of retrofit controls for the model units was estimated, and cost-effectiveness values were determined. The cost-effectiveness of acidic materials control was compared with the cost-effectiveness where applicable of SO₂ which is co-emitted with acidic materials. Additionally, promising research and development activities relevant to acid materials control were also examined.

Results and Recommendations

The major combustion and industrial sources of directly emitted acidic materials that were identified during this study are presented in Table 1. For most source categories, emissions were estimated using emissions factors and combustion and process capacities found in the literature. Utility and industrial boilers are by far the largest acidic emissions sources in the U.S., producing about 760,000 Mg (830,000 tons) and 180,000-250,000 Mg (200,000-275,000 tons) of acidic material emissions per year, respectively. It was also estimated that emissions of directly emitted acidic materials represent only 2% of the annual emissions of SO₂, NO_x, and VOC (which are acid precipitation precursors) from stationary sources.

Based on information obtained in the literature, model plants, including the most applicable acidic material controls, were developed for sources that emit over 4,500 Mg (5,000 tons) of acidic material per year. This cutoff point allowed the project to focus on source categories with the greatest

emissions. The major sources considered include utility and industrial boilers, Claus sulfur recovery plants, catalytic cracking units, primary copper smelters, coke oven plants, primary aluminum smelters, and municipal solid waste incinerators. Although Kraft pulp mills, gypsum plants, and cement plants are large sulfate emissions sources, they were not analyzed further because the compounds emitted are alkaline or pH neutral. In addition, gypsum ponds were identified as a source category emitting large amounts of HF. However, HF emissions from gypsum ponds are reduced by water treatment methods, whereas this study focused primarily on controls which treat acidic gases. Thus, no further analysis was attempted.

Little performance data is available concerning the control of acidic emissions by currently operating control systems. Therefore, the systems chosen for model unit development are generally those which are demonstrated for control of SO₂ and NO_x and provide the greatest potential for control of acidic material emissions.

Cost analyses were performed to estimate the costs required for retrofitting the selected control systems to model plants. Table 2 summarizes the control systems analyzed for each significant source category and their respective cost-effectiveness. Cost-effectiveness is defined as the unit annual cost for removing the acidic materials. If SO₂ is present in the emission stream, controls were selected for concurrent removal of SO₂ and the acidic materials. Typically, the volume of SO₂ is quite large compared to that of acidic materials. Therefore, cost-effectiveness is considerably improved if calculated for the combined removal of acidic materials and SO₂. The combined cost-effectiveness values are included in Table 2.

The greatest obstacle in this study was the lack of available performance data for acidic emissions control systems. No information was available concerning the control of acid nitrates. All test data for removing acid sulfates were presented in terms of H₂SO₄ mist control and show a wide range of removal efficiencies. Therefore, it would be desirable if research could be directed toward quantitating the acid sulfate and acid nitrate control performances of existing applicable gaseous and particulate controls. While data for HCl and HF removal are also lacking, the need for research in this area is not urgent, because HCl and HF have high affinities to the alkaline solutions commonly used by FGD systems and, as indicated by the limited test data, removal is expected to be high.

The technologies identified as being most applicable to reducing directly emitted acidic materials are wet/dry scrubbing techniques. Conventional electrostatic precipitators and fabric filters are not as effective because acidic material frequently forms downstream of where these devices are typically located. For this reason, the most cost-effective control devices for sulfates, fluorides, and chloride are the same as would be employed for SO₂. Conventional combustion modification techniques, used to control NO_x emissions from boilers, were identified as the best commercially available methods for reducing nitrate emissions.

Table 1. National Emissions Estimates for Identified Source Categories

Source Category	Acid Sulfate Emissions (10 ³ Mg/yr) 10 ³ tons/yr	Nitrate Emissions (10 ³ Mg/yr) 10 ³ tons/yr	HCl Emissions (10 ³ Mg/yr) 10 ³ tons/yr	HF Emissions (10 ³ Mg/yr) 10 ³ tons/yr	Total Emissions (10 ³ Mg/yr) 10 ³ tons/yr	Year Data Reported
Utility Boilers						
Coal	107 (117)	64 (70)	496 (546)	60 (66)	756 (831)	1980/1982
Residual Oil	25 (28)					
Distillate Oil	3.6 (4)					
Industrial Boilers						
Coal	20-81 (25-89)	32 (35)	88 (96)	10.6 (11.5)	182-248 (203-273)	1980/1982
Residual Oil	5-10.4 (5.5-11.5)					
Distillate Oil	27 (30)					
Municipal Solid Waste			20 (22)		20 (22)	—
Catalytic Cracking	11.3 (12.5)				11.3 (12.5)	1983
Primary Copper	8.6-10.4 (9.5-11.5)				8.6-10.4 (9.5-11.5)	1984
Primary Aluminum	0.18-0.41 (0.2-0.45)			5.9 (6.5)	6.1-6.3 (6.7-7)	1983
Gypsum Ponds				5.9 (6.5)	5.9 (6.5)	1980
Claus Plants	5.4 (6)				5.4 (6)	1980
Coke Ovens	5 (5.5)				5 (5.5)	1983
Propylene Oxide Manufacturing			2.7-4.1 (3-4.5)		2.7-4.1 (3-4.5)	1980
Residential Boilers			2.7 (3)	0.2 (0.25)	2.9 (3.25)	1974
Sulfuric Acid Plants	1.8 (2)				1.8 (2)	1982
Phosphoric Acid Plants				0.14 (0.15)	0.14 (0.15)	1980
Triple Superphosphate Manufacturing				0.18 (0.2)	0.18 (0.2)	1980
Primary Zinc	0.2 (0.25)				0.2 (0.25)	1983
Diammonium Phosphate Manufacturing				0.2 (0.25)	0.2 (0.25)	1980
HF Manufacturing				0.01-1.2 (0.01-1.35)	0.01-1.2 (0.01-1.35)	1980

Table 2. Summary of Controls Analyzed and Cost-Effectiveness

Source Category/ Process Capacity	Fuel Type ^a	Control	Acidic Species Controlled	Cost-Effectiveness of Removal			
				Acidic Material \$/Mg (\$/ton)		Acidic Material + SO ₂ \$/Mg (\$/ton)	
Industrial Boilers^b							
30.5 GJ/hr (30 MMBtu/hr)	HSC LSC DO RO	Sodium-Based Scrubber	Sulfates, HCl, HF	39,300	(35,700)	810	(740)
				24,400	(22,200)	2,640	(2,400)
			Sulfates	359,000	(327,000)	4,890	(4,440)
				492,800	(448,000)	1,110	(1,010)
	HSC LSC DO RO	Dual Alkali Scrubber	Sulfates, HCl, HF	86,100	(78,300)	1,770	(1,610)
				66,000	(60,000)	7,130	(6,480)
			Sulfates	999,000	(908,000)	13,600	(12,360)
				1,200,000	(1,090,000)	2,720	(2,470)
	HSC LSC DO RO	Lime Spray Dryer	Sulfates, HCl, HF	72,600	(66,000)	1,910	(1,730)
				59,900	(54,400)	7,930	(7,210)
			Sulfates	626,000	(569,000)	15,400	(14,000)
				704,000	(640,000)	2,920	(2,660)

Table 2. (Continued)

Source Category/ Process Capacity	Fuel Type ^a	Control	Acidic Species Controlled	Cost-Effectiveness of Removal				
				Acidic Material \$/Mg (\$/ton)		Acidic Material + SO ₂ \$/Mg (\$/ton)		
406 GJ/hr (400 MMBtu/hr)	HSC	Sodium-Based Scrubber	Sulfates, HCl, HF	18,900	(17,200)	390	(350)	
	LSC			7,000	(6,300)	750	(680)	
	DO			89,000	(81,000)	1,180	(1,070)	
	RO			200,000	(182,000)	450	(410)	
	HSC	Dual Alkali Scrubber	Sulfates, HCl, HF	20,600	(18,700)	420	(380)	
	LSC			11,400	(10,300)	1,220	(1,110)	
	DO			156,000	(142,000)	2,060	(1,870)	
	RO			249,000	(226,000)	560	(510)	
	HSC	Lime Spray Dryer	Sulfates, HCl, HF	21,700	(19,800)	560	(510)	
	LSC			14,300	(13,000)	1,810	(1,650)	
	DO			119,000	(108,000)	2,870	(2,610)	
	RO			172,000	(156,000)	710	(640)	
	HSC	Low Excess Air	NO _x ^c	132	(120)	—	—	
	LSC			9	(8)	—	—	
	Coal	Overfire Air	NO _x ^c	112	(102)	—	—	
	Utility Boiler^b							
2,0311 GJ/hr (2,000 MMBtu/hr)	HSC	Limestone Wet Scrubber	Sulfates, HCl, HF	64,700	(58,800)	1,130	(1,030)	
	LSC			52,600	(47,800)	4,960	(4,510)	
	RO			291,000	(264,600)	2,350	(2,140)	
	HSC	Wellman-Lord System	Sulfates, HCl, HF	94,600	(86,000)	1,660	(1,510)	
	LSC			62,800	(57,100)	5,930	(5,390)	
	HSC	Lime Spray Dryer	Sulfates, HCl, HF	62,100	(56,500)	1,140	(1,040)	
	LSC			47,300	(43,000)	4,650	(4,230)	
	Coal	Low NO _x Burners	NO _x ^c	123	(112)	—	—	
	Coal	Low Excess Air	NO _x ^c	7	(6)	—	—	
	Oil			2	(2)	—	—	
	Coal	Overfire Air	NO _x ^c	96	(87)	—	—	
	Oil			131	(119)	—	—	
	5,078 GJ/hr (5,000 MMBtu/hr)	HSC	Limestone Wet Scrubber	Sulfates, HCl, HF	45,700	(41,600)	800	(730)
		LSC			37,600	(34,200)	3,550	(3,230)
		RO			229,000	(208,000)	1,850	(1,680)
		HSC	Wellman-Lord System	Sulfates, HCl, HF	74,300	(67,600)	1,300	(1,190)
LSC		49,400			(44,900)	4,670	(4,240)	
HSC		Lime Spray Dryer	Sulfates, HCl, HF	48,000	(43,600)	880	(800)	
LSC				35,300	(32,000)	3,460	(3,150)	
Coal		Low NO _x Burners	NO _x ^c	71	(64)	—	—	
Coal		Low Excess Air	NO _x ^c	3	(3)	—	—	
Oil				1	(1)	—	—	
Coal		Overfire Air	NO _x ^c	56	(51)	—	—	
Oil				83	(75)	—	—	
Claus Plants								
10 Mg/day (11 tons/day)			Amine Tail Gas Treatment	Sulfates	242,800	(220,300)	2,420	(2,200)
100 Mg/day (110 tons/day)					77,200	(70,000)	770	(700)
250 Mg/day (275 tons/day)					54,900	(49,800)	550	(500)

Table 2. (Continued)

Source Category/ Process Capacity	Fuel Type ^a	Control	Acidic Species Controlled	Cost-Effectiveness of Removal			
				Acidic Material \$/Mg (\$/ton)		Acidic Material + SO ₂ \$/Mg (\$/ton)	
Fluid Catalytic Cracking Units							
2,500 m ³ /sd (15,725 bbl/sd) ^j	ISF ^d	Sodium-Based Scrubber ^e	Sulfates	93,640	(84,950)	1,090	(990)
	HSF ^d			63,450	(57,560)	740	(670)
8,000 m ³ /sd (50,320 bbl/sd) ^j	ISF ^d			62,580	(56,770)	730	(660)
	HSF ^d			47,830	(43,390)	560	(510)
Primary Copper Smelters							
115,000 Mg/yr (127,000 tons/yr)		Sulfuric Acid Plant ^f	Sulfates	9,800	(8,900)	130	(120)
Coke Oven Plants							
2000 Mg/day (220 tons/day)		Vacuum Carbonate System	Sulfates	11,700	(10,600)	950	(870)
6000 Mg/day (6600 tons/day)				6,900	(6,300)	570	(520)
Municipal Solid Waste (MSW)							
380 Mg/day (420 tons/day)	MSW	Sodium-Based Scrubber ^g	HCL	1,900	(1,730)	1,020	(1,120)
730 Mg/day (800 tons/day)	MSW			1,480	(1,340)	970	(880)

^aHSC = high-sulfur coal; LSC = low-sulfur coal; DO = distillate oil; RO = residual oil.

^bBoiler capacities presented in terms of heat input.

^cNo emissions data, specifically in terms of acid nitrate emissions, were available. Thus, all cost-effectiveness results are given in terms of controlling NO_x emissions.

^dCatalytic cracking unit feed rather than fuel. ISF = intermediate-sulfur feed (1.5 wt. % S); HSF = high-sulfur feed (3.5 wt. % S).

^eHigh energy venturi scrubber using soda-ash-based scrubbing liquor.

^fSingle stage acid plant.

^gEmploys caustic-soda-based scrubbing liquor.

^hExcludes benefits of concurrent SO₂ reductions.

^jm³/sd: cubic meter per stream day

bbl/sd: barrel per stream day.

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The complete report, entitled "Cost of Controlling Directly Emitted Acidic Emissions from Major Industrial Sources," (Order No. PB 88-234 190/AS; Cost: \$19.95, subject to change) will be available only from:

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