ACIDIC EMISSIONS CONTROL TECHNOLOGY AND COSTS

ACIDIC EMISSIONS
CONTROL TECHNOLOGY
AND COSTS

Library of Congress Catalog Card Number: 89-8712
ISBN: 0-8155-1208-2
ISSN: 0090-516X
Printed in the United States

Published in the United States of America by
Noyes Data Corporation
Mill Road, Park Ridge, New Jersey 07656

10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Emmel, T.E.
Acidic emissions control technology and costs / by T.E. Emmel, J.T. Waddell, R.C. Adams.
p. cm. -- (Pollution technology review, ISSN 0090-516X ; no. 168)
Includes bibliographies and index.
ISBN 0-8155-1208-2 :
1. Fume control. 2. Acid deposition--Environmental aspects. I. Waddell, J.T. II. Adams, R.C. (Radford Carter), 1922-
III. Title. IV. Series.
TD884.5.E44 1989
363.73'866--dc20 89-8712
CIP

Foreword

This book describes acidic emissions control technology and costs. The objectives of the study were: (1) to identify and characterize stationary combustion and industrial sources of directly emitted acidic materials in the United States; (2) to evaluate the technical feasibility of control techniques for these sources; and (3) to estimate the costs of applying these control technologies.

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 precipitations. 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 (SO_2, NO_X, and VOC).

The book gives results of estimates, using a model plant approach, of costs for retrofitting selected acidic emission control systems to 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.

Sources of directly emitted acidic materials were identified via a literature search. For most source categories, emissions were estimated using emission factors and combustion and process capacities found in the literature. To focus project funding on source categories with the greatest emissions, model units were developed for those sources which emit 4,500 Mg (5,000 tons) or more of acidic material per year. These model units were then used as bases to establish control techniques and determine control costs.

Utility and industrial boilers are the largest U.S. sources, emitting approximately 760,000 Mg (830,000 tons) and 180,000 to 250,000 Mg (200,000 to 275,000 tons) of acidic material per year, respectively. Total direct emissions of acidic materials represent an estimated 2% of annual acid precipitation precursor (SO_2, NO_X, and VOC) emissions from stationary sources.

Results of this 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 emissions, the information in this book could be used to evaluate the cost effectiveness of controlling local sources of directly emitted acidic materials versus sources of long range precursor emissions.

The greatest obstacle in this study was the lack of available performance data for acidic emissions control systems. Thus, the control systems chosen for model development and cost estimation are generally those which are commercially demonstrated for control of SO_2 and NO_X and provide the greatest potential for control of acidic material emissions. Promising research and development activities relevant to acidic materials control were also examined.

The information in the book is from *Cost of Controlling Directly Emitted Acidic Emissions from Major Industrial Sources,* prepared by T.E. Emmel, J.T. Waddell, and R.C. Adams of Radian Corporation for the U.S. Environmental Protection Agency, July 1988.

The table of contents is organized in such a way as to serve as a subject index and provides easy access to the information contained in the book.

Advanced composition and production methods developed by Noyes Data Corporation are employed to bring this durably bound book to you in a minimum of time. Special techniques are used to close the gap between "manuscript" and "completed book." In order to keep the price of the book to a reasonable level, it has been partially reproduced by photo-offset directly from the original report and the cost saving passed on to the reader. Due to this method of publishing, certain portions of the book may be less legible than desired.

Abbreviations and Symbols

ACFM	actual cubic feet per minute
bbl	barrel
Btu	British thermal unit
C	Celcius
cm	centimeter
DOE	Department of Energy
F	Fahrenheit
FGD	flue gas desulfurization
ft	feet
GJ	gigajoule
HCl	hydrogen chloride
HF	hydrogen fluoride
hr	hour
H_2S	hydrogen sulfide
kg	kilogram
kJ	kilojoule
kPa	kilopascal
lb	pound
LT	long ton (equal to one megagram)
m	meter
Mg	megagram
mg	milligram
min	minute
MMBtu	million Btu
NO_x	nitrogen oxides
PC	pulverized coal
ppmv	parts per million (by volume)
psi	pounds per square inch
s	second
SCFD	standard cubic feet per day
sd	stream day
SO_x	sulfur oxides
SO_2	sulfur dioxide
TPD	tons per day
VOC	volatile organic compounds

NOTICE

The materials in this book were prepared as accounts of work sponsored by the U.S. Environmental Protection Agency. This information has been reviewed by EPA and the other participating Federal Agencies, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. On this basis the Publisher assumes no responsibility nor liability for errors or any consequences arising from the use of the information contained herein.

Final determination of the suitability of any information or procedure for use contemplated by any user, and the manner of that use, is the sole responsibility of the user. The reader is warned that caution must always be exercised when dealing with hazardous materials, such as acidic emissions, and expert advice should be sought at all times.

Contents and Subject Index

1. 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 precipitations. 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 (SO_2, 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 United States; 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 via review and analysis of 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 emissions, 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.

The results of the study are summarized in Section 2. To identify and characterize sources of directly emitted acidic materials, national acidic materials emissions of all combustion and industrial sources were identified by means of a literature search (Section 3 and Appendix A). Model units were then developed for those sources which emit 4,500 Mg (5,000 tons) or more of acidic material per year (Section 4). 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 control retrofits for the model units were estimated and cost-effectiveness values were determined (Section 5). The cost-effectiveness of acidic materials control was compared with the cost-effectiveness where applicable of SO_2 which is co-emitted with acidic materials. Promising research and development activities relevant to acid materials control were also examined (Section 6).

2. Results and Recommendations

The major combustion and industrial sources of directly emitted acidic materials that were identified during this study are presented in Table 2-1. 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 approximately 760,000 Mg (830,000 tons) and 180,000-250,000 Mg (200,000-275,000 tons) of acidic material emissions per year, respectively. The bases for all emissions data given in Table 2-1 are discussed and referenced in both Section 3 and Appendix A. It was also found that emissions of directly emitted acidic materials represent only 2 percent of the annual emissions of SO_2, 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 cut off point allowed the project funding to be focused on those 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 selected for further analysis 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

TABLE 2-1. 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
(1) Utility Boilers						
Coal	107 (117)	64 (70)	496 (546)	60 (66)	756 (831)	1980/1982
Residual Oil	25 (28)					
Distillate Oil	3.6 (4)					
(2) 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)					
(3) Municipal Solid Waste			20 (22)		20 (22)	--
(4) Catalytic Cracking	11.3 (12.5)				11.3 (12.5)	1983
(5) Primary Copper	8.6-10.4 (9.5-11.5)				8.6-10.4 (9.5-11.5)	1984
(6) Primary Aluminum	0.18-0.41 (0.2-0.45)			5.9 (6.5)	6.1-6.3 (6.7-7)	1983
(7) Gypsum Ponds				5.9 (6.5)	5.9 (6.5)	1980
(8) Claus Plants	5.4 (6)				5.4 (6)	1980
(9) Coke Ovens	5 (5.5)				5 (5.5)	1983
(10) Propylene Oxide Manufacturing			2.7-4.1 (3-4.5)		2.7-4.1 (3-4.5)	1980
(11) Residential Boilers			2.7 (3)	0.2 (0.25)	2.9 (3.25)	1974
(12) Sulfuric Acid Plants	1.8 (2)				1.8 (2)	1982
(13) Phosphoric Acid Plants				0.14 (0.15)	0.14 (0.15)	1980
(14) Triple Super Phosphate Manufacturing				0.18 (0.2)	0.18 (0.2)	1980
(15) Primary Zinc	0.2 (0.25)				0.2 (0.25)	1983
(16) Diammonium Phosphate Manufacturing				0.2 (0.25)	0.2 (0.25)	1980
(17) HF Manufacturing				0.01-1.2 (0.01-1.35)	0.01-1.2 (0.01-1.35)	1980

chosen for model unit development are generally those which are demonstrated for control of SO_2 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 2-2 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 removal of the acidic materials. If SO_2 is present in the emission stream, controls were selected for concurrent removal of SO_2 and the acidic materials. Typically, the volume of SO_2 is quite large compared to the volume of acidic materials. Therefore, cost-effectiveness is considerably improved if calculated for the combined removal of acidic materials and SO_2. The combined cost-effectiveness values are included in Table 2-2. The bases for data presented in Table 2-2 are discussed and referenced in Section 5.

The greatest obstacle in this study was the lack of available performance data for acidic emissions control systems. All test data that could be readily obtained is summarized in Table 2-3. No information was available concerning the control of acid nitrates. All test data for removal of acid sulfates are presented in terms of H_2SO_4 mist control and show a wide range of removal efficiencies. Therefore, it would be desirable if research efforts were 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. This is 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 the acidic materials may still be in a gaseous state at the operating conditions where these devices are typically located. As such, it was concluded that the most cost effective control devices for,

TABLE 1-2. SUMMARY OF CONTROLS ANALYZED AND COST-EFFECTIVENESS

Source Category/ Process Capacity	Fuel Type[a]	Control	Acidic Species Controlled	Cost-Effectiveness of Removal			
				Acidic Material[d] $/Mg	($/ton)	Acidic Material + SO_2 $/Mg	($/ton)
Industrial Boilers[b]							
30.5 GJ/hr (30 MMBtu/hr)	HSC	Sodium-Based Scrubber	Sulfates, HCl, HF	39,300	(35,700)	810	(740)
	LSC			24,400	(22,200)	2,640	(2,400)
	DO		Sulfates	359,000	(327,000)	4,890	(4,440)
	RO			492,800	(448,000)	1,110	(1,010)
	HSC	Dual Alkali Scrubber	Sulfates, HCl, HF	86,100	(78,300)	1,770	(1,610)
	LSC			66,000	(60,000)	7,130	(6,480)
	DO		Sulfates	999,000	(908,000)	13,600	(12,360)
	RO			1,200,000	(1,090,000)	2,720	(2,470)
	HSC	Lime Spray Dryer	Sulfates, HCl, HF	72,600	(66,000)	1,910	(1,730)
	LSC			59,900	(54,400)	7,930	(7,210)
	DO		Sulfates	626,000	(569,000)	15,400	(14,000)
	RO			704,000	(640,000)	2,920	(2,660)
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		Sulfates	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		Sulfates	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		Sulfates	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]							
2,031 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		Sulfates	291,000	(264,600)	2,350	(2,140)

TABLE 2-2. SUMMARY OF CONTROLS ANALYZED AND COST-EFFECTIVENESS (Continued)

Source Category/ Process Capacity	Fuel Type[a]	Control	Acidic Species Controlled	Cost-Effectiveness of Removal	
				Acidic Material[b] $/Mg ($/ton)	Acidic Material + SO_2 $/Mg ($/ton)
	HSC LSC	Wellman-Lord System	Sulfates, HCl, HF	94,600 (86,000) 62,800 (57,100)	1,660 (1,510) 5,930 (5,390)
	HSC LSC	Lime Spray Dryer	Sulfates, HCl, HF	62,100 (56,500) 47,300 (43,000)	1,140 (1,040) 4,650 (4,230)
	Coal	Low NO_x Burners	NO_x[c]	123 (112)	---
	Coal Oil	Low Excess Air	NO_x[c]	7 (6) 2 (2)	--- ---
	Coal Oil	Overfire Air	NO_x[c]	96 (87) 131 (119)	--- ---
5,078 GJ/hr (5,000 MMBtu/hr)	HSC LSC RO	Limestone Wet Scrubber	Sulfates, HCl, HF Sulfates	45,700 (41,600) 37,600 (34,200) 229,000(208,000)	800 (730) 3,550 (3,230) 1,850 (1,680)
	HSC LSC	Wellman-Lord System	Sulfates, HCl, HF	74,300 (67,600) 49,400 (44,900)	1,300 (1,190) 4,670 (4,240)
	HSC LSC	Lime Spray Dryer	Sulfates, HCl, HF	48,000 (43,600) 35,300 (32,000)	880 (800) 3,460 (3,150)
	Coal	Low NO_x Burners	NO_x[c]	71 (64)	---
	Coal Oil	Low Excess Air	NO_x[c]	3 (3) 1 (1)	--- ---
	Coal Oil	Overfire Air	NO_x[c]	56 (51) 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 2-2. SUMMARY OF CONTROLS ANALYZED AND COST-EFFECTIVENESS (Continued)

Source Category/ Process Capacity	Fuel Type[a]	Control	Acidic Species Controlled	Cost-Effectiveness of Removal: Acidic Material[h] \$/Mg (\$/ton)	Cost-Effectiveness of Removal: Acidic Material + SO_2 \$/Mg (\$/ton)
Fluid Catalytic Cracking Units					
2,500 m^3/sd (15,725 bbl/sd)[i]	ISF[d] HSF[d]	Sodium-Based Scrubber[e]	Sulfates	93,640 (84,950) 63,450 (57,560)	1,090 (990) 740 (670)
8,000 m^3/sd (50,320 bbl/sd)[i]	ISF[d] HSF[d]			62,580 (56,770) 47,830 (43,390)	730 (660) 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 (2200 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)

[a] HSC = high-sulfur coal; LSC = low-sulfur coal; DO = distillate oil; RO = residual oil.

[b] Boiler capacities presented in terms of heat input.

[c] No 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.

[d] Catalytic cracking unit feed rather than fuel. ISF = intermediate-sulfur feed (1.5 wt. % S); HSF = high-sulfur feed (3.5 wt. % S).

[e] High energy venturi scrubber using soda ash-based scrubbing liquor.

[f] Single stage acid plant.

[g] Employs caustic soda-based scrubbing liquor.

[h] Excludes benefits of concurrent SO_2 reductions.

[i] m^3/sd: cubic meter per stream day
bbl/sd: barrel per stream day.