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Project Summary

Methodology for Development of an Independent Combustion Source NO_x Inventory: And Its Application to 150 Counties in the Northeastern United States

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This study was performed to demonstrate a new methodology for developing a combustion source fuel use and emissions inventory. The demonstration area encompassed 150 counties within a 200-mi (320-km) radius of the Adirondack Mountains in New York State, believed to be representative of the Northeastern U.S.

A complete combustion inventory of nitrogen oxides (NO_x) emissions was developed for the 150 counties. All sectors (residential, commercial, transportation, utility, and industrial) were included. In the industrial sector, the methodology entailed: (1) identifying all major combustion processes and associated equipment, and (2) developing NO_x emission factors. This approach produced a list of 28 facilities and 73 processes, believed to include all significant combustion sources in the 150-county study area. An approach was also developed for treating all fuel consumption not accounted for by installations that include major combustion processes. The latter block of fuel consumption was translated into "residual" industrial area source NO_x emissions.

As intended, the project demonstrated fully the essential elements of a methodology that would allow development of county-by-county NO_x inventory for all fuel burning in all or any part of the U.S., without resorting to user surveys or inventories based on such surveys. The data base it establishes also can be used to calculate other combustion-related emissions.

Although the procedures of this methodology were not fully optimized in this study, they are straightforward, well documented, and easily modified as new data are uncovered.

Study results showed that area sources account for 92 percent of the fuel consumption (excluding utilities) and 64 percent of NO_x emissions (including utilities) in the study area. Transportation is the dominant contributor. Boilers are the dominant point sources of NO_x emissions, and residual oil accounts for 52 percent of the industrial boiler fuel burned in this area.

This Project Summary was developed by EPA's Industrial Environmental 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

By the late 1960s, the most significant sources of major air pollutants such as NO_x and sulfur oxides (SO_x) had been identified and put in some perspective; however, no data bank contained information on the size, location, type and amount of pollution, and other impact factors for all major air pollution sources.

In the late 1960s and early 1970s, work began on developing a comprehensive inventory. The Clean Air Act of 1970 gave impetus to this effort, resulting in EPA's establishment of the National Emissions Data System (NEDS), a data bank containing information on pollutant discharges from all types of area and point sources. Most of the data in this computerized data base are generated by state agencies. Data quality is a function of the resources available to the states for collection of information from facilities that generate pollution. Although the imput data are screened to some extent, the accuracy of the various data has not been well defined. Some users believe that data for certain components (e.g., utilities, and iron and steel plants) are well documented; whereas, data for other smaller components (e.g., foundries and industrial boilers) are not.

As a result, in the past several years the need for better and more comprehensive regional and local inventories has been considered in several quarters. For example, the data base for industrial and commercial boilers is thought to be inadequate in light of the pollution problem they are now believed to present.

This study was performed to demonstrate another methodology for developing a combustion source and emissions inventory. The approach was novel in that is was not based primarily on field investigation or survey data. Instead, fuel use information and industrial statistics published by government and industry groups were used to identify fuel-consuming facilities and to estimate their emissions of NO_x. It was hoped that the project would show the feasibility of an inventory that was neither subject to the errors inherent in those based on surveys, nor as costly as those involving field verification.

A study area encompassing 150 counties within a 200-mi (320-km) radius of the Adirondack Mountains in New York State (Figure 1) was chosen to demonstrate this approach to developing a combustion source fuel use and emissions inventory.

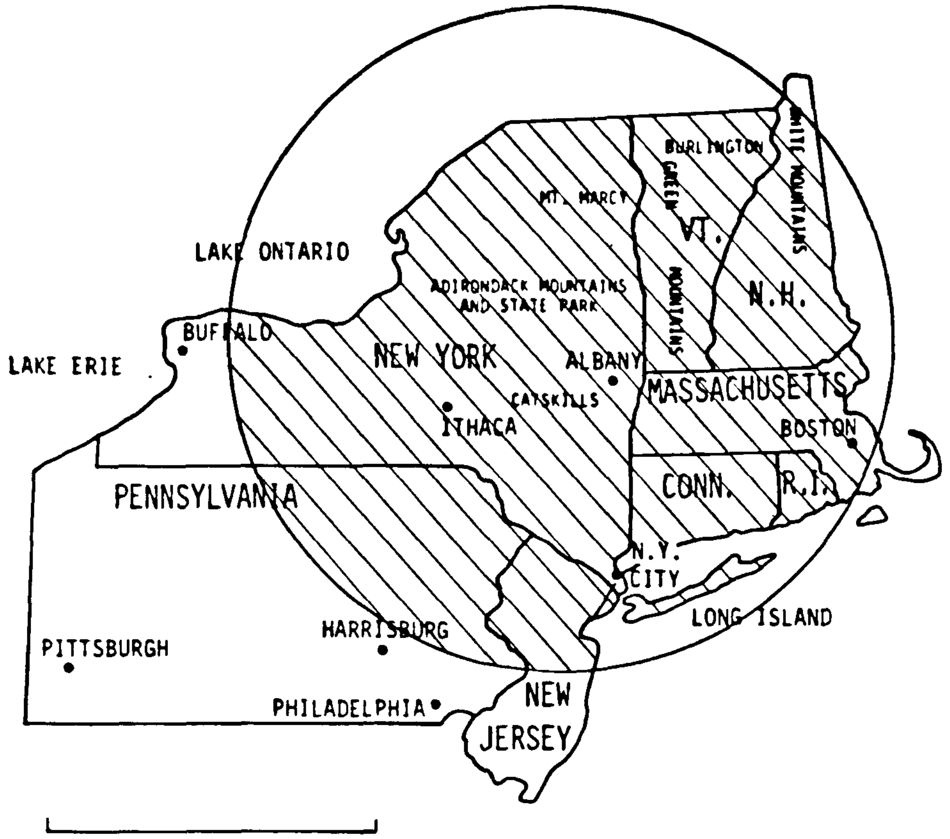

Figure 1. *The 150-county study area (shaded).*

General Approach

This study's approach to residential, commercial, and transportation sectors was straightforward in that these sectors were treated as traditional area sources (mobile or small and widely dispersed, such as automobiles and residential furnaces), and an accepted methodology was used to compute energy consumption on a county-by-county basis. Because it is already extensively documented, the utility sector also presented few problems. The industrial sector, which has traditionally been the most difficult to assess, was systematically analyzed to provide a better overall perspective of the combustion sources in that sector.

For the residential and commercial sectors, it was assumed that fuel use was proportional to population, and the sector fuel consumption for individual states was prorated to individual counties. County fuel use data were then converted to NO_x emissions, using emisson factors developed from analyzing fuel burning practices in the sector.

The transportation sector includes liquid fuels used in motor vehicles and natural gas used in pipeline transport of fuel. The combustors involved in pipeline transport (internal combustion engines and gas turbines) were not broken down to the county level, however. Consumption of liquid fuels was assumed to be proportional to the number of registered motor vehicles in the individual counties. Emission factors were derived by analysis of information on emissions from various types of motor vehicles, and area NO_x emissions were estimated by county.

Because the type and amount of fuel used, types and locations of combustors, etc., are well documented for the utility sector, demonstration of the ability to generate county-by-county emission inventories for this sector was deemed unnecessary for this study.

The industrial sector presented the biggest challenge. Prior to this study, this sector had never been systematically investigated to identify major combustion sources. Because this sector uses fuel in major direct-fired processes, large industrial boilers, and a wide variety of smaller combustors (e.g., stationary internal combustion engines, gas turbines, ovens, and dryers), a more complex approach was required.

The analysis of industrial sector NO_x emissions began with a systematic evaluation of specific blocks of fuel burning that make up the total for industrial combustion. The major blocks of fuel combustion are well defined and documented in the literature, which served as a source of the analysis.

The combustion hardware was more clearly defined by systematic analyses that divided all industrial fuel burning into that burned by identifiable "major point sources" (estimated by fuel consumption of at least 100 x 10^9 Btu (or kJ /yr) and that consumed by area sources. This classic approach, consistent with the NEDS treatment, allows direct comparisons to be made despite using an independent approach.

Because no previous study defined the total population of point sources, a search based on all the "industries" (defined for the manufacturing sector in the Census of Manufacturers) was undertaken as an important part of the industrial fuel analysis. As a first step, the Standard Industrial Classification (SIC) code industries represented by 4-digit codes in the Census data bank were screened to eliminate all those with a total annual fuel use of less than 100 x 10^9 Btu/establishment. It was assumed that this limit would prevent overlooking any major direct-fired point sources in the industries with low average annual fuel consumption. The industries eliminated by this formula were reviewed to determine if this was a correct assumption.

At the beginning of the analysis of the industrial sector, a decision also was made not to include industries in which fuel consumption could be attributed principally to boilers or foundries. Because of their numbers and widely varying sizes, these were to be the subject of an independent analysis. Industries that involved assembly line work where space heat requirements were high were also excluded. Together, these two screening criteria reduced the total number of industries for further investigation from 450 to 114.

The final group of 114 industries were investigated to identify direct-fired processes that were considered to be major point sources (because of fuel use estimated to be over 100 x 10^9 Btu/yr), to identify the establishments where these direct-fired processes were employed, and to estimate the amount of fuel used and the resulting NO_x emissions.

In the end, a list of 28 types of facilities employing 73 types of processes was developed for the 150-county study area (Table 1). These processes, together with foundries and industrial boilers, are believed to present the most complete definition of the population of fuel-consuming industrial processes that had been developed up to the time the list was completed.*

Analysis of industrial boilers with heat input of ≥250 x 10^6 Btu/h was based on existing data bases such as NEDS, the U.S. Department of Energy's (DOE's) Major Fuel Burning Installation (MFBI) survey, and PEDCo in-house data accumulated during plant visits connected with DOE projects.

After the major industrial point sources and the large boilers† had been identified, the sum of the fuel consumption for these point sources was subtracted from the total industrial fuel consumption reported by the Department of Energy. The balance of the industrial energy consumption was then treated in a manner similar to that used for the residential, commercial, and transportation sectors. Fuel consumption and NO_x emission estimates were then generated for the following categories:

Area sources	Point sources
Residential sector	Industrial boilers
Commercial sector	Electric utilities
Transportation sector	Direct-fired processes
Industrial nonpoint sources	

Applying the Methodology to the Study Area

The methodology was applied to the study area in four steps:

1) Identification and location of major point sources.
2) Development of fuel consumption estimates for major point sources.
3) Development of fuel consumption estimates for area sources.
4) Determination of emission factors and calculation of emissions for point and area sources.

Although the study area represents a limited fraction of the total country, the results produced are of interest beyond their usefulness in demonstrating the methodology. In general, the identified direct-fired sources and boilers accounted for a surprisingly small percentage of total industrial fuel consumption (30 percent in the study area). Thus, "residual" industrial energy usage (classified as area source consumption) is sizable, ranking third in the categories of emissions (behind transportation and electric utilities) for the study area.

When comparing the results of this study, remember that utility emissions are included in the NO_x totals, but utility fuel consumption is not part of the fuel total. Study results showed that area sources are the major contributors to NO_x emission in the study area. These sources accounted for 64 percent of total NO_x emissions (excluding utilities). Transportation was the dominant contributor (48 percent), but the combined total for the residential and commercial sectors was significant (about 10 percent). Area sources also accounted for 92 percent of the fuel consumed in this study area (excluding utilities).

Among industrial point sources, boilers were the dominant emitter of NO_x emissions, and residual oil accounted for 52 percent of the industrial boiler fuel use.

Table 2 summarizes point and area source NO_x emissions in the study area. Table 3 compares the results of this methodology with NEDS data covering the same area.

Conclusions

The methodology for developing a major point source combustion population (i.e., the use of Standard Industrial Classification Codes) was judged to be successful. The resulting list of 28 facilities and 73 processes is believed to include combustion sources of any consequence in the 150-county area.

The straightforward well-documented methodologies developed for calculating plant production, direct-fired fuel consumption, and NO_x emissions do not rely primarily on survey data from state agencies. Although these procedures were not optimized in this study, they can be easily modified as new data are uncovered.

In contrast, the procedures used to calculate industrial boiler fuel consumption and NO_x emissions rely heavily on NEDS and other completed studies. Although these sources could be used to identify boilers smaller than the 25-MW equivalent used for this study, the data base for industrial boilers is generally weaker than that for other important stationary sources, a situation that will prevail until a well-conceived survey of the existing boiler population is conducted.

The methodology for calculating "residual" industrial fuel consuming sources and NO_x emissions needs more work. If a study included individual states in their entirety, data from the State Energy Data Base and the Census of Manufacturers could be combined to provide a better

*Work subsequent to that reported here has expanded the group of establishments to 45 and the group of processes to 100. For the most part, these processes are very close to the estimated fuel consumption limit of 100 x 10^9 Btu.

†Only 25-MW or larger boilers were considered in this study; however, given sufficient resources, boilers in the 10- to 25-MW range probably could be inventoried with reasonable accuracy by this same approach.

Table 1. List of Major Fuel-Consuming Facilities and Processes

Facility[a]	Process[a]
Petroleum refineries	Atmospheric distillation
	Vacuum distillation
	Thermal operation
	Catalytic cracking
	Catalytic reforming
	Hydrocracking
	Hydrorefining
	Alkylation
	Aromatic manufacturing
Petrochemical plants	Ammonia (steam hydrocarbon reforming)
	Benzene, toluene, xylene
	Butadiene (naphtha cracking)
	Carbon black (oil furnace process)
	Ethanol (naphtha cracking)
	Ethylene/propylene (naphtha cracking)
	Methanol (low pressure)
Industrial organic chemical plants	Dimethyl terephthalate (Dynamit Nobel)
	Styrene (Monsanto)
Industrial inorganic chemical plants	Borax (drying)
	Lithium hydroxide (calcination)
	Sodium carbonate (monohydrate)
Phosphate rock and basic fertilizer plants	Potash (calcination)
	Potash (drying)
	Potash (leaching)
	Sodium phosphate (fusion/calcination)
	Sodium phosphate (crystallization/drying)
Pulp mills	Kraft
Gypsum plants	Drying/calcination
Lime plants	Calcination
Brick and tile plants	Firing
Lightweight aggregate plants	Expansion
Cement plants	Wet and dry
Container glass plants	Melting
Flat glass plants	Melting
Pressed and blown glass plants	Melting

Facility	Process
Diatomite plants	Drying/calcination
Mineral wool plants	Melting
Integrated iron and steel plants	Sintering
	Coking
	Steelmaking
	Melting
	Slabbing/blooming
Mini and midi iron and steel plants	Melting
	Slabbing/blooming
Iron foundries	Melting
Copper smelters and refineries	Smelting
	Roasting
	Cathode melting
	Arsenic oxide (roasting)
Lead smelters and refineries	Sintering
	Smelting
	Softening
	Desilverizing
	Debismuthing
	Refining
Zinc smelters and refineries	Roasting
	Sintering
	Electrothermic reduction
	Secondary materials preparation
Titanium smelters	Chlorination
	Reduction
	Leaching
	Drying
Tin smelters	Smelting
Magnesium smelters	Calcination
Aluminum smelters	Sweating
	Smelting
Copper smelters and refineries	Sweating
	Smelting
	Refining
Lead smelters	Smelting
Aluminum sheet, plate, and foil plants	Melting
	Heat treating

[a]*The order in which facilities and processes are listed reflects the authors' logical grouping of the industries, with respect to their relation to each other.*

perspective of the residual component of industrial fuel consumption.

The methodology reported here is flexible and easily modified. This strength has already been demonsrated in that the methodology has been further refined since this project was concluded.

Table 2. *Summary of Point and Area Source NO_x Emissions in the 150-County Study Area (10^3 short tons or 9.1×10^5 kg)*[a]

	Area Sources				Point sources			NOx total			
	Traditional				Industrial						
State	(1) Transportation	(2) Residential	(3) Commercial	(4) Industrial residual	(5) Boilers	(6) Direct fired	(7) Electric utility	Industrial 4, 5, and 6	Area 1, 2, 3, and 4	Point 5, 6, and 7	State total
Connecticut	71.7	8.3	3.9	13.0	1.2	1.3	33.4	15.5	96.9	35.9	132.8
Massachusetts	118.7	13.6	10.9	8.8	1.1	0.8	78.3	10.7[b]	152.0	80.2	232.2
New Hampshire	21.3	1.8	0.4	0.7	0.4	1.1	12.2	2.2	24.2	13.7	37.9
New Jersey	161.9	12.2	16.5	9.4	2.6	9.3	55.4	21.3[c]	200.0	67.3	267.3
New York	274.9	31.8	42.7	12.2	34.2	16.3	191.9	62.7[d]	361.6	242.4	604.0
Pennsylvania	117.4	8.8	4.6	51.7	4.3	23.6	124.5	79.6[e]	182.5	152.4	334.9
Rhode Island	20.2	2.6	1.2	1.6	0.1	0.2	2.1	1.9	25.6	2.4	28.0
Vermont	15.1	1.3	0.3	1.1	0	0	0.1	1.1	17.8	0.1	17.9
Study area total	801.2	80.4	80.5	98.5	43.9	52.6	497.9	195.0	1060.6	594.4	1655.0

[a]Based on 1978 data.
[b]Value is 97 percent of 1978 state total based on the population of the counties included in the analysis.
[c]Value is 84 percent of 1978 state total based on the population of the counties included in the analysis.
[d]Value is 97 percent of 1978 state total based on the population of the counties included in the analysis.
[e]Value is 33 percent of 1978 state total based on the population of the counties included in the analysis.

Table 3. *Comparison of NO_x Emissions Estimates for the 150-County Study Area with 1980 NEDS*[a] *Values*

Emission source	NO_x estimates, 10^3 tons (9.1×10^5 kg)/yr — 1980 NEDS values	This study
Mobile source fuel combustion		
Highway vehicles	894.1	801.2
Stationary source fuel combustion		
Electric generation	423.7	497.9
Industrial (boilers and residual sources)	194.2	142.4
Residential/commercial/institutional	168.6	160.9
Industrial processes and combustion	24.8	52.6
Chemicals	(3.36)	(0.3)
Petroleum refining	(3.07)	(5.1)
Metals	(2.69)	(26.4)
Mineral products	(11.65)	(19.4)
Wood products	(0.25)	(1.3)
Other	(3.81)	(0.0)
Mobile source subtotal	894.1 (52.4%)	801.2 (48.4%)
Stationary source subtotal	811.3 (47.6%)	853.8 (51.6%)
Total	1705.4	1655.0

[a] EPA's National Emissions Data System.

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The complete report, entitled "Methodology for Development of an Independent Combustion Source NO_x Inventory: And Its Application to 150 Counties in the Northeastern United States," (Order No. PB 84 189 943; Cost: $19.00, subject to change) will be available only from:
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