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Comparison of respiratory symptoms among community residents near waste disposal incinerators

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A previous survey found that residents near a hazardous waste incinerator reported more respiratory symptoms than residents of a nearby community. To explore the possibility that these findings might have been due to the use of a rural control site, far removed from urban pollution, we expanded the analysis to include reports of respiratory symptoms from residents of six additional communities. Residents of each of four study communities were exposed to the plumes of biomedical, municipal or hazardous waste combustors. For each study community, a comparison community was surveyed that was distant from major point sources of air pollution. Over 4200 respondents were queried by telephone about respiratory symptoms, smoking and other risk factors such as chemical exposures in the workplace and home, and provided a subjective assessment of air quality in their neighborhoods. Differences in symptom prevalence between each study community and its respective control community, as well as a combined control group, were explored, controlling for factors other than community exposure that may affect respiratory health. Results indicate a higher prevalence of all self-reported respiratory symptoms in one community near a hazardous waste incinerator compared with its control community. While this relationship persisted after controlling for perceived air quality and when compared with a combined control group, only respiratory symptoms of long duration remained significant. These results suggest that further examination of the respiratory health of residents living near this waste combustor source is warranted.

Keywords: incinerators, respiratory symptoms, hazardous waste

Introduction

Waste disposal is a growing problem in the United States and other developed countries (Marty 1993). Although incineration is a technological solution for municipal, biomedical and even hazardous wastes, the effect of various emissions and by-products on exposed community residents has not been thoroughly studied (Marty 1993). The technology to accurately measure the multitude of contaminants emitted from incinerators is limited and the health effects of low level and/or multiple exposures are not known (Ostry *et al.* 1993). Community advocates and

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incinerator operators present subjective views of these health effects, and the extent to which perceived threats to health adversely affect community residents is not known. Prior to expanding this technology and putting new incinerators on line, it is important to know if waste incineration adversely affects the health of nearby community residents. Respiratory symptoms are one of the most sensitive markers for adverse health effects associated with air pollution (Phillips and Silbergeld 1985, Christensen *et al*. 1995, Hall *et al.* 1995). A cross-sectional study was conducted in 1992 that evaluated respiratory health effects of people residing near a hazardous waste incinerator compared to a reference community (Feigley *et al.* 1994). To explore the possibility that these results were a product of the particular nature of the control group (rural control site, far removed from urban pollution) used in the study, we expanded the analysis to include reports of respiratory symptoms from residents of six additional communities. Four of the total eight communities studied were near waste combustors.

Methods

Two independent cross-sectional surveys were conducted in North Carolina (Shy *et al*. 1995) and South Carolina (Feigley *et al.* 1994) using identical survey instruments, sampling scheme for selection of the households and training protocols for the interviewers. Even though both the surveys utilized similar study methods, the data from these surveys have never been analyzed together. The current analysis combines data from both studies, using common analytic techniques to investigate the respiratory effects of various forms of incineration. There were four communities, three in North Carolina (communities A, B, and C) and one in South Carolina (community D), near waste combustors that are defined as:

- *Community A:* near a biomedical waste incinerator that burned boxed biomedical waste materials such as pathology tissue samples, microbiological waste, discarded instruments and utensils, needles, paper, plastics, pigments, and discarded biologicals and chemicals used in laboratories. No radioactive wastes were incinerated and no air-pollution controls were in use at this facility during the first year of the study (Rothenbacher *et al.* 1994, Shy *et al.* 1995).
- *Community B:* near a publicly owned municipal waste incinerator, that primarily burned plastics, paper, and other household wastes. Waste gases were passed through a 73-m stack equipped with an electrostatic precipitator (Shy *et al.* 1995).
- *Community C:* near an industrial furnace that was permitted to burn liquid hazardous wastes in one of its four rotary kilns at a maximum rate of $1220\,\mathrm{l\,h^{-1}}$. The kilns were fed with raw slate to produce a lightweight aggregate used in construction materials. At the time of this study, this facility was not burning liquid wastes, but was using fuel oil or coal (Shy *et al.* 1995).
- *Community D:* near a commercial, multiple chamber, fixed hearth, hazardous waste incinerator that was permitted (in 1983) to burn solid, liquid and gaseous wastes and was equipped with a wet scrubber for control of stack emissions.

Study communities were defined as all households within a 2×5-km ellipse for communities A, B and C, and 8×5-km ellipse for community D, centered on the incinerator and with the long axis parallel to the most frequent wind direction. Four control communities, one for each study community (control A, control B, control C, control D), with socioeconomic characteristics and population densities similar to the respective study community were selected. The control

Table 1. Concentration of particulate matter less than 10 μm aerodynamic diameter (PM_{10}) measured in the study and control communities during the year of the survey

	Concentration ($\mu g\ m^{-3}$)			
Community	*N**	*Mean†*	*Minimum†*	*Maximum†*
Study A	53	33	10	74
Control A	60	37	13	77
Study B	72	22	8	49
Control B	70	24	9	49
Study C	61	18	7	34
Control C	63	21	7	36
Study D	51	30	12	60
Control D	–	–	–	–

* Number of valid samples. 12-h samples for communities A, B, and C; 24-h samples for study community D.
† Mean of a.m. and p.m. values for communities A, B, and C; 24-h composite sample for study community D.

communities A, B, C, and D were located upwind (with respect to the most frequent wind directions) and separated from their study communities by 5.2, 5.7, 10, and 25 km respectively at their closest point. The concentration of particulate air pollution $< 10\ \mu m$ in diameter (PM_{10}) was similar in the study and comparison communities, although this information was not available for comparison community D. The range, as shown in Table 1, was between 7 and 77 $\mu g\ m^{-3}$, well below the National Ambient Air Quality Standard of 150 $\mu g\ m^{-3}$.

Dwelling units were identified in both the study and control communities from census data, tax rolls, telephone directories, and on-site inspection of the areas. Households for the study were selected by a research firm under contract, that was experienced in sampling procedures. Initially, letters were mailed to all households to introduce them to the study and prepare them for the telephone interview. Subjects were told that they were part of the 'Health and Clean Air Study', but pollution sources of interest were not specified. In each participating household, attempt was made to obtain information directly from all household residents except children. Telephone interviews were conducted by trained interviewers. For the analyses reported in this paper, we used only information from residents who were aged 18 and older, and who responded for themselves (Hornung *et al.* 1996).

Information on respiratory symptoms was collected using a modified version of a respiratory disease questionnaire developed by the American Thoracic Society (Ferris 1978). The surveys were performed during Fall of 1992 and Spring of 1993. This questionnaire included information on respiratory health, demographics, household characteristics, smoking, chemical exposure at work and perception of outdoor air quality. Symptoms were classified into those of long duration (present during the past 12 months) and symptoms of short duration (present during the past month). The long duration respiratory symptoms used as outcome variables were defined as follows:

- *Wheeze:* report of wheezing or whistling in the chest at anytime in the past 12 months in the absence of a cold, or being breathless when the wheezing noise was present and its frequency during the past 12 months (less than three times/more than three times).

- *Morning cough and phlegm, or wheeze:* report of either wheezing or coughing and bringing up phlegm or thick mucous from the chest 4 days per week or more on getting up or first thing in the morning for as much as 3 months of the year, during the past 12 months, and the duration of these symptoms (less than 3 years/more than 3 years).
- *Awaken at night:* report of awakening during the night by an attack of coughing or a feeling of tightness in the chest or an attack of shortness of breath at anytime in the pat 12 months.

In addition, outcome variables were created from five symptoms of short duration (lasting for a whole day during the past month) including eye irritation, sore throat, cough, runny nose and nasal irritation. We examined groups reporting one or more, two or more, or three or more symptoms.

Several demographic characteristics and potential confounders were identified and included ethnicity (African-American or white), gender, marital status (married or divorced, separated, widowed, single) and educational status (high school graduation or more education versus less than high school graduation). The length of time living within 2 miles (3.2 km) of the current address was categorized as less than 3 years versus 3 or more years.

The following household characteristics possibly related to respiratory symptoms were also included in the analysis as potential confounders: cooking with a non-electric source; using non-electric sources for heating; using central air conditioning; having a problem with mold or mildew at home; using a humidifier regularly; and having household pets. Other variables evaluated included work exposure to chemicals, dusts or fumes and perception that the air in the neighborhood was polluted, smokey or smelly (very often).

Logistic regression models were developed for each outcome variable and were adjusted for all potential confounders. The crude and adjusted odds ratios for each outcome variable within each study community were obtained by comparing them with their respective comparison communities and with a combined control group in which data from all four control communities were grouped. A combined control group was used to determine if the effects seen in one pair of communities would remain when using a larger, more diverse control community.

Results

Participation rate in each of the eight study areas were similar in the community pairs. The overall participation rate ranged from 66% to 88% (Table 2). Since we did not have information on the sociodemographic characteristics of the non-participants, comparisons were made to the population in the corresponding geographical areas from where the study population was selected. It was seen that in general, there were fewer men and African Americans among the respondents compared to the general population (Table 3). However, the mean age and educational level of the participants were comparable to that of the general population. The sampled population may not be very representative of the people in the geographic area since we picked areas close to and far from the incinerator to represent the heavily exposed and unexposed people. It is known that people tend to segregate according to race and socioeconomic status.

The demographic characteristics for the 4205 respondents and the number of subjects in each study community, its respective comparison community and in the combined control group are shown in Table 4. The mean age of the residents was similar between the study communities and

Table 2. Participation of households in the different study and comparison communities

	Community A		*Community B*		*Community C*		*Community D*	
Households	*Study*	*Control*	*Study*	*Control*	*Study*	*Control*	*Study*	*Control*
Completed	406	409	511	501	357	408	413	335
Eligible	576	585	727	757	470	509	472	426
Participation rate (%)	71	70	70	66	76	80	88	79

Community A: Study: Huntersville, NC. Control: Cornelius, NC.
Community B: Study: Charlotte, NC (near municipal incinerator). Control: Charlotte, NC (Shamrock area).
Community C: Study: Aquadale, NC. Control: Oakboro, NC. Control: Oakboro, NC.
Community D: Study: Rock Hill, SC. Control: Chester, SC.
Participation rate = (Completed households/Eligible households) ×100.

their respective comparison communities and ranged from 44 to 51 years. In general, from 63% to 93% of the residents in all eight communities had lived there at least 2 years. While the respondents in the study and comparison communities were similar on several characteristics, there were some interesting differences. There was a lower percentage of African-Americans in study communities A and C, and a higher percentage in study community D, compared to their respective control communities. The percentage who had graduated from high school was higher in study communities A, B and D compared to their control communities. There were lower proportions of current smokers in communities B and C compared to their control communities. Differences among the communities was also found for those who use non-electric sources for cooking and heating and for those who used air conditioning. However, there were no significant differences among respondents of the study and respective comparison communities in terms of mold problems at home, humidifier use, pets at home and work exposures. Perception of poor outdoor air quality was much higher in study community D, compared to its control community (23% compared to 8%).

Comparison of the reported symptoms showed that a significantly higher proportion of respondents in study community D reported all of the respiratory symptoms (both long and short duration symptoms) with respect to the control community (Fig. 1 and 2). For example, 19.1% of the people in the study community reported wheeze, 23% reported morning cough and phlegm, and 36.9% reported awakening at night compared to 13%, 14.6% and 24.3% respectively in the control community. More than half of the study population reported having at least one short duration symptom compared to 44.6% of the control population. Residents in study community C did not differ significantly from the control community with respect to any of the reported respiratory symptoms except for one. About 28.9% of the study population reported 'awaken at night' compared to only 22.8% of the control population. There were no significant differences in reported respiratory symptoms of long or short duration between study and control communities A and B.

Logistic regression models, adjusted for potential confounders, found that residents of study community D were 1.5 times as likely as those in the comparison community to report wheeze, 1.7 times more likely to report cough and phlegm or wheeze, and 1.8 times more likely to awaken at night with symptoms (Table 5). All of these odds ratios were statistically significant and remained so even when using a combined control community. A similar pattern was found

Table 3. Comparison of Sociodemographic (percentage) characteristics of the study and control communities with that of the population in the respective geographical areas

	Community A				*Community B*[a]			*Community C*				*Community D*			
	Study	*HT*[b]	*Control*	*CR*[c]	*Study*	*Control*	*CL*[d]	*Study*	*AD*[e]	*Control*	*OB*[f]	*Study*	*RH*[g]	*Control*	*CH*[h]
Mean age	44	47	46	41	44	47	45	51	48	50	46	51	47	51	48
African-American	3.5	14.1*	7.3	20.3*	13.0	14.2	28.3*	0.0	6.5*	7.7	24.1*	35.5	31.9	21.9	40.2*
Men	44.6	48.1	40.0	47.4*	43.9	37.9	48.8*	40.4	49.1*	33.7	46.3*	39.3	46.1*	37.3	47.4*
HS Graduate +	92.4	89.8	87.8	85.7	95.5	90.4	89.9*	69.5	72.3	71.2	71.6	80.6	79.3	69.8	73.5

* p-value < 0.05 when comparing each study/control community with its respective county population. [a]Both the study and control population in Community B resided in areas within Charlotte, NC; [b]HT, Huntersville town, NC; [c]CR, Cornelius town, NC; [d] CL, Charlotte, NC; [e]AD, Aquadale, NC; [f]OB, Oakboro town, NC; [g]RH, Rock Hill, SC; [h]CH, Chester county, SC.

Table 4. Characteristics (percentages) of four study and control communities and a combined control community

	Community A		*Community B*		*Community C*		*Community D*		
	Study $N = 514$	*Control* $N = 518$	*Study* $N = 624$	*Control* $N = 622$	*Study* $N = 453$	*Control* $N = 510$	*Study* $N = 540$	*Control* $N = 424$	*Combined Control* $N = 2074$
Age (mean ± SD)	44 ± 15	46 ± 16	44 ± 15	47 ± 16	51 ± 17	50 ± 17	51 ± 16	51 ± 16	48 ± 17
Reside(0–2 yrs)	37.2	31.7	28.6	19.6*	8.0	9.0	11.5	6.8*	17.3
African-American	3.5	7.3*	13.0	14.2	0.0	7.7*	35.5	21.9*	12.4
Men	44.6	40.0	43.9	37.9*	40.4	33.7*	39.3	37.3	37.4
HS Graduate +	92.4	87.8*	95.5	90.4*	69.5	71.2	80.6	69.8*	80.8
Married	82.9	71.2*	69.1	62.4*	76.8	68.6*	70.7	79.3*	69.6
Current smoker	15.6	17.6	13.3	20.9*	14.6	19.8*	21.1	21.0	19.8
Non-electric cook	6.8	28.8*	3.2	11.4*	4.6	1.0*	13.5	10.4	12.9
Non-electric heat	46.5	32.0*	39.3	23.0*	44.4	41.6	51.3	48.1	35.0
Central air-cond	86.4	72.4*	92.2	71.1*	62.0	54.1	67.4	52.6*	63.5
Poor air quality	9.3	8.3	9.3	11.1	15.5	11.0	23.2	8.0*	9.7

* p-value < 0.05 when comparing each community pair.

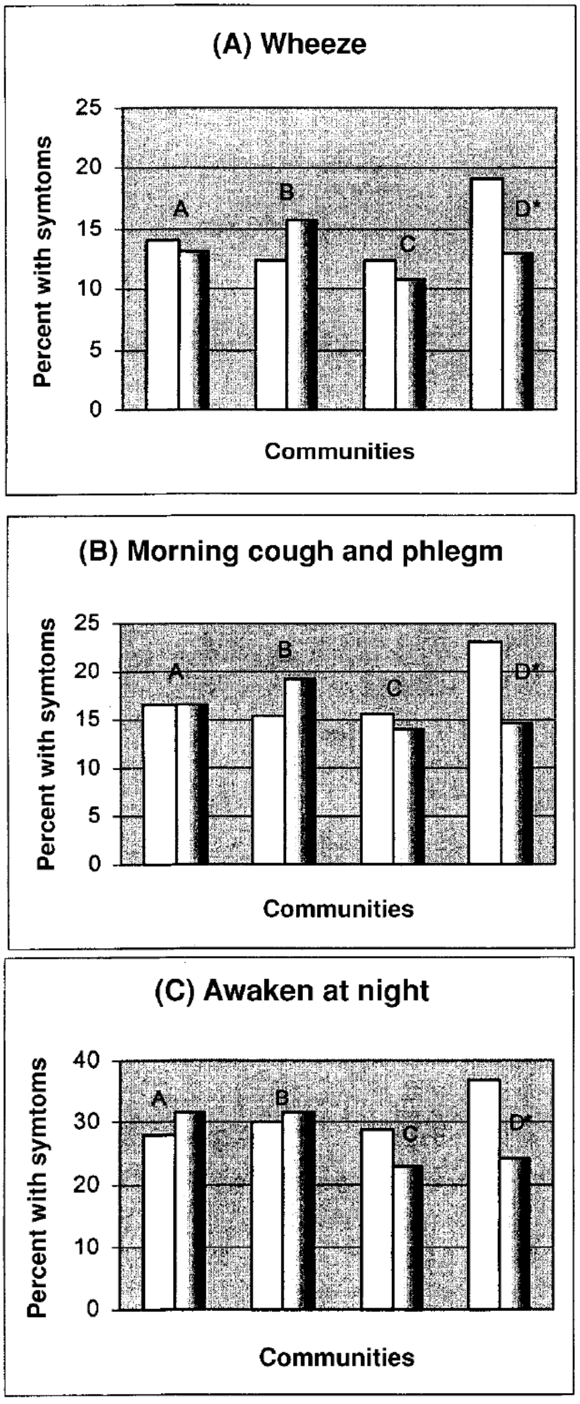

Fig. 1. Percent of participants with the different long duration symptoms in the study and control communities. Clear bars represent study communities and shaded bars the respective control communities; *indicates higher than corresponding control community rate at a p-value < 0.05

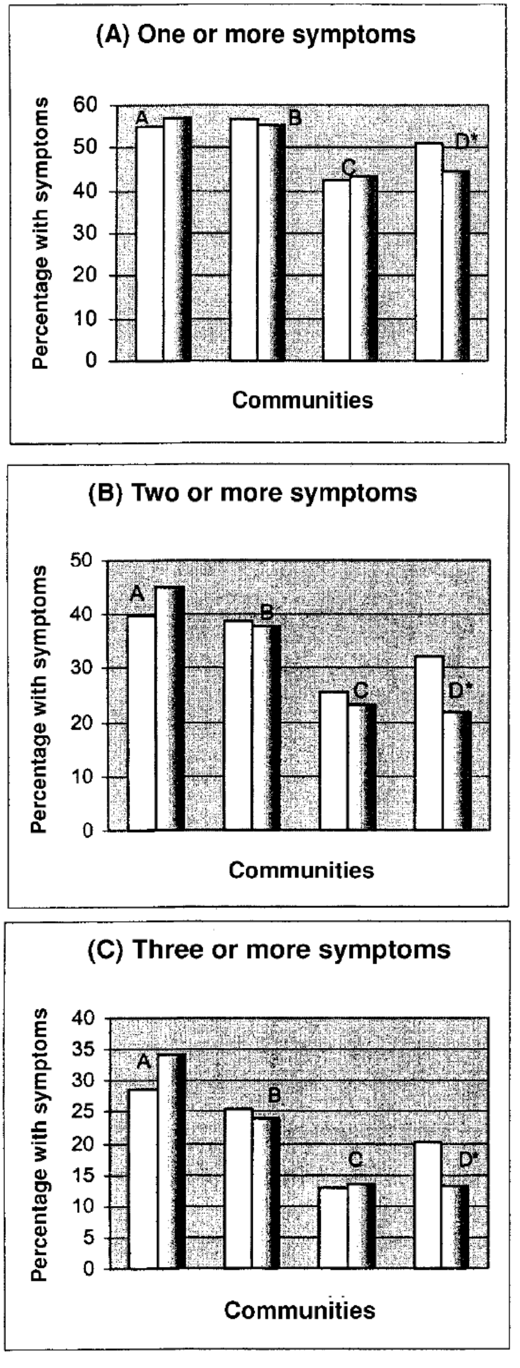

Fig. 2. Percentage of participants with the different short duration symptoms in the study and control communities. The clear bars represent the study communities and the shaded bars the respective control communities; Short duration symptoms included eye irritation, sore throat, cough, runny nose, nasal irritation that lasted for a whole day, during the past month; *indicates higher than corresponding control community rate at a p-value < 0.05

Table 5. Crude and adjusted odds ratios for study and control communities and a combined control community

	Community A			*Community B*			*Community C*			*Community D*		
	COR[a]	*AOR*[b]	*AOR*[c]	*COR*[a]	*AOR*[b]	*AOR*[c]	*COR*[a]	*AOR*[b]	*AOR*[c]	*COR*[a]	*AOR*[b]	*AOR*[c]
Long duration symptoms												
Wheeze	1.1	1.2	1.2	0.8	0.9	1.1	1.2	1.1	0.9	1.6*	1.5*	1.5*
Morning Cough and Phlegm or Wheeze	1.0	1.1	1.2	0.8	1.0	1.1	1.1	1.1	0.9	1.7*	1.7*	1.5*
Awaken at night	0.8	0.8	1.0	0.9	1.0	1.1	1.4*	1.3*	1.1	1.8*	1.8*	1.4*
Short duration symptoms[d]												
One or more	0.9	0.8	1.1	1.1	1.1	1.1	1.0	1.0	0.7*	1.3*	1.3	1.0
Two or more	0.8	0.7*	1.2	1.0	1.2	1.3	1.1	1.1	0.7*	1.7*	1.6*	1.0
Three or more	0.8	0.6*	1.2	1.1	1.2	1.1	1.0	–	0.6*	1.7*	1.6*	1.0

* p-value < 0.05
[a]Crude odds ratio.
[b]Odds ratio, adjusted for age, gender, ethnicity, length of stay within 2 miles of present residence, education, smoking, use of a non-electric source for cooking or heating, central air conditioning, problem with mold at home, use of a humidifier, pets, exposure to chemicals at work, perceived poor air quality.
[c]Odds ratio (adjusted as above), but using a combined control group.
[d]Symptoms included eye irritation, sore throat, cough, runny nose, nasal irritation that lasted for a whole day, during the past month.

for the short duration symptoms especially for a report of ≥2 or ≥3 symptoms (adjusted odds ratio = 1.6; Table 5). However, this excess did not remain when using the combined control group (odds ratio = 1.0).

For study community C, only the odds ratio for awaken at night was statistically significant, but did not remain so when compared to the combined control community (Table 5). The adjusted odds were close to unity for the short duration symptoms in community and when using the combined control group, the odds ratios became significantly less than one.

No significant differences were found in the report of symptoms of long duration in paired communities A and B (Table 5). The adjusted odds ratios also failed to show any elevated risks and ranged from 0.8 to 1.2 (Table 5). There were no significant differences in the report of symptoms of short duration in community B (Table 5). The adjusted odds ratio ranged from 1.1 to 1.2 and from 1.1 to 1.3 when using the combined control group. The results indicated the study group in community A to be less likely to report symptoms of short duration as compared to its control community. This finding however, did not remain statistically significant when compared with the combined control group.

Prior studies indicated that individuals concerned about the environment usually over-report their health symptoms compared to people with less concern (Ostry *et al.* 1993). To examine the effect of perception of outdoor air quality on our findings, we reanalyzed the data removing the adjustment for perceived outdoor air quality. We found that this had no effect on the odds ratios for all symptoms for communities A, B and C (whether compared to each respective control community or to the combined control group). For community D, exclusion of the adjustment for perceived air quality increased the odds ratios for all symptoms. This increase was larger when comparing with its control D community than when using the combined control community. Also, there was a larger change in the odds ratios for symptoms of longer duration than was found for symptoms of shorter duration. Therefore, results from analysis that adjusted for perceived poor air quality are reported in Table 5.

Discussion

This study aimed at investigating the previously reported high prevalence of respiratory symptoms found near a hazardous waste incinerator (study community D); (Feigley *et al.* 1994) by combining data from eight communities, using standard analyses, and common definitions, exclusion criteria and case definitions. Further, analyses were conducted both by pairing study and comparison communities, and by using a common control group. Although symptoms from residents of study community D remained higher than the comparison community, combining community D with a larger study allowed us to determine if the problems previously identified might be due to a rural control site, far removed from urban pollution. By combining four control groups, the effect of our original control group was diluted especially for the short-duration symptoms. As the current analyses indicate, only respiratory symptoms of long duration remained statistically significant when compared with the combined control group. In general, there was about a 50% increased reporting of respiratory symptoms of long duration in community D compared to the combined control group. No such differences were evident in the other communities.

The observed difference in the prevalence of reported respiratory symptoms in the study communities could be a result of the differences in the incinerators with respect to the type of waste burnt, design and the air pollution control devise in use. At the time of the study, the incinerator in community D was the only site that was using externally generated waste as a supplemental fuel. The other incinerators even though active, were not burning liquid waste during the survey. The different incinerators also differ with respect to design and the air pollution control devices utilized. For example, incinerator in community D used a cyclonic wet scrubber, the municipal incinerator in community B used an electrostatic precipitator, and the incinerator in community C was in the process of obtaining upgraded air pollution control devices at the time of study. However no such air-pollution control device was in place in community A at the time or prior to the survey. Both cyclonic wet scrubbers and electrostatic precipitators are used to achieve high particulate matter collection efficiency and are capable of reaching collection efficiencies of 90% to greater than 98% (Spaite and Buckle 1977, Wark *et al.* 1998). The collection efficiency depends upon the particulate physical characteristics (e.g. size, density) and the carrier gas characteristics as well as collector design. In addition to particulate matter, the wet scrubber also has a high collection efficiency (estimated to exceed 90%) for acid gases. Another reason for our findings could be that community D and its control community were well apart, (25 km) whereas the other comparison communities were much closer (5–10 km apart) to their respective study communities. However, the reporting of long duration symptoms still showed up to be significantly higher in community D when using the combined control group.

Other distinguishing characteristics of study community D are the high percentage of African-Americans (35.5%) and the high proportion of residents in study community D, as compared to its comparison community, who showed concerns about air quality. It has been shown that African-American children have a higher prevalence of respiratory problems than white children, even after adjusting for all known confounders (Gold *et al.* 1993). Although only adults were included in this analysis, and ethnicity was controlled in the analysis, it is unclear what effect ethnic distribution could have had on our results. Also, neither controlling for perceived poor air quality nor removing it altogether substantially changed the results of the study.

It is important to understand if the presence of a point source with heavy media coverage will bias the resident's report of symptoms (Ostry *et al.* 1993). If this were likely to happen, it would happen through reporting of symptoms, rather than diagnosed problems that could be verified through medical records. We used self-reported respiratory symptoms because they have been shown to be sensitive measures of effect in environmental studies where multi-chemical, and low-dose exposures occur even though these symptoms are subjective measures and difficult to verify (Phillips and Sibergeld 1985, Christensen *et al.* 1995), Hall *et al.* 1995).

Although we were not able to determine the cause of these respiratory symptoms (e.g., other sources of pollution near the combustor sites) (Ware *et al.* 1993), studies such as this will assist in developing plans to further explore the possible health impact of environmental contaminants. Even though the results of this study does not warrant a generalization of the overall effect of incinerators on respiratory health, it does indicate the capability of some incinerators in causing respiratory complaints. This issue need to be addressed further in future studies taking into consideration the inclusion of other sources of pollution and the verification of the symptomatology.

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