Environmental Tobacco Smoke Concentrations in No-Smoking and Smoking Sections of Restaurants

William E. Lambert, PhD, Jonathan M. Samet, MD, and John D. Spengler, PhD

ABSTRACT

To characterize the effectiveness of a local ordinance that restricts smoking in restaurants to one third of the seating area, this study made simultaneous measurements of two markers of environmental tobacco smoke, respirable suspended particles and nicotine, in the smoking and no-smoking sections of seven restaurants. The mean concentrations of respirable suspended particles and nicotine were 40% and 65% lower, respectively, in the no-smoking than in the smoking sections, indicating substantial but not complete protection against exposure. (*Am J Public Health* 1993;83:1339–1341)

Introduction

Although ordinances and policies establishing no-smoking seating areas inside public and commercial buildings are designed to protect indoor air from contamination, there have been few published reports comparing levels of environmental tobacco smoke in no-smoking and smoking areas. To characterize the effectiveness of a regulation separating smokers from nonsmokers in restaurants, we measured concentrations of respirable particles and nicotine simultaneously in the smoking and no-smoking areas of seven restaurants in Albuquerque, NM. Each of the restaurants was in compliance with the city ordinance restricting smoking to one third of the total indoor seating. Under the Albuquerque Clean Indoor Air Ordinance,[1] there can be no more than two areas designated for smokers; however, all restaurants participating in this monitoring study had established a single area for smokers.

Methods

The idea for the study originated in discussions with two local television news journalists who were preparing a story on the ordinance. During May and June 1989, the journalists obtained permission to monitor the air in the no-smoking and smoking seating areas of seven Albuquerque restaurants. The seating capacity of each of the restaurants exceeded 100. No restaurant operator refused their request for access, although several of the operators indicated that they were not in favor of the smoking ordinance.

A mass-flow controlled pump was used to sample respirable particles and nicotine vapor. Particles and aerosols of less than 2.5 μm aerodynamic diameter were collected with impactors operating at a flow rate of 4 L per minute.[2] Particle mass deposited on tared Teflon membrane filters (2.0 μm pore size) was determined with a Cahn 21 Electro Balance (Cahn Instruments Inc, Cerritos, Calif) after equilibration in a temperature- and humidity-controlled room. After the air stream passed through the particle filter, nicotine vapor was collected on sodium bisulfate–treated glass fiber filters (Millipore Corp, Bedford, Mass). A modification of the method described by Hammond and coworkers[3] was used to extract nicotine from the filter; the extracted nicotine was quantified by flame ionization gas chromatography (Model GC7A, Shimadzu Inc, Columbia, Md).

The journalists, with assistance from the authors, placed the monitors at the sites. Each restaurant was sampled on 2 consecutive days from 11:00 AM to 11:00 PM. Because of concerns about the method's limit of detection and sensitivity, the samples were collected across two 12-hour periods without changing filters. Therefore, the respirable suspended particle and nicotine measurements represent two 12-hour integrated samples and cover two luncheon and two dinner periods. The no-smoking and smoking sections were sampled simultaneously. In all but two locations, the impactor heads were placed in the middle of the no-smoking and smoking seating areas, 90 to 180 cm (3 to 6 ft) above the floor, to be within the usual breathing zone of the patrons. The two exceptions to this placement protocol were restaurant 1, where the sampler in the smoking section was placed on an overhead beam 300 cm (10 ft) above the floor, and the no-smoking section of restaurant 3, where the impactor head was placed 60 cm (2 ft) above the floor. The impactor heads were not placed on the tops of tables where the customers were served; rather, they were placed on

William E. Lambert and Jonathan M. Samet are with the New Mexico Tumor Registry, Cancer Center, University of New Mexico School of Medicine, Albuquerque. John D. Spengler is with the Department of Environmental Health, Harvard School of Public Health, Boston, Mass.

Requests for reprints should be sent to William E. Lambert, PhD, New Mexico Tumor Registry, University of New Mexico Medical Center, 900 Camino de Salud NE, Albuquerque, NM 87131.

This paper was accepted with revisions December 16, 1992.

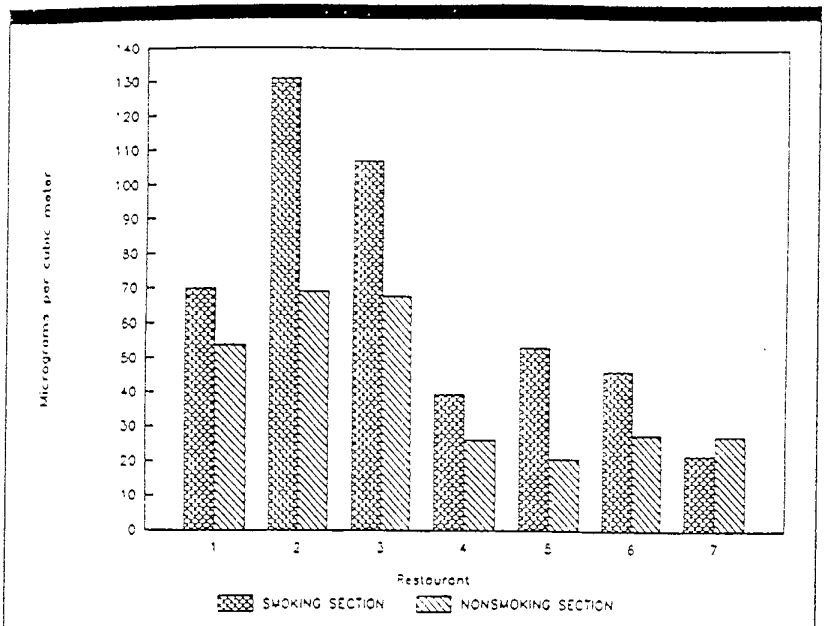

FIGURE 1—Mean concentrations of respirable suspended particulate matter in the smoking and no-smoking sections of seven Albuquerque, NM, restaurants.

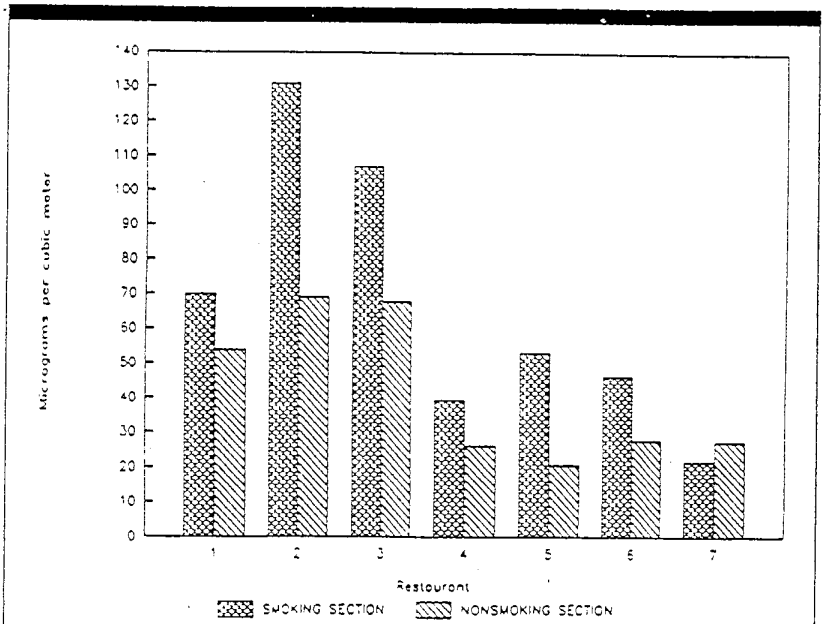

FIGURE 2—Mean concentrations of nicotine in the smoking and no-smoking sections of seven Albuquerque, NM, restaurants.

other furniture or on countertops available in the seating area. An attempt was made to place the samplers in locations where they would not be obvious to patrons, and the restaurant managers were instructed not to call them to the attention of their customers.

Other than to place the samplers in the middle of the no-smoking and smoking sections, no attempt was made to characterize the relation of the sampler locations to the layout of the seating areas or to monitor the number of restaurant patrons or the tobacco smoking activity.

Results

The integrated measurements of respirable suspended particulate matter and nicotine for the no-smoking and smoking areas of restaurants are presented in Figures 1 and 2. In the no-smoking areas of restaurants, respirable suspended particle levels ranged from 20.7 to 69.0 $\mu g/m^3$, with a median of 27.8 $\mu g/m^3$ (Figure 1). In the smoking areas, respirable suspended particle levels ranged from 21.7 to 131.0 $\mu g/m^3$, with a median of 53.2 $\mu g/m^3$. In six of the seven restaurants, respirable suspended particle levels were lower in the no-smoking areas than in the smoking areas (Wilcoxon paired sample test, $P = .03$). The median difference was 18.6 $\mu g/m^3$. The Spearman rank correlation of respirable suspended particle concentrations in no-smoking and smoking areas was .75.

Nicotine concentrations ranged from 0.2 to 2.8 $\mu g/m^3$, with a median of 1.0 $\mu g/m^3$, in no-smoking areas and from 1.5 to 3.8 $\mu g/m^3$, with a median of 3.2 $\mu g/m^3$, in smoking areas (Figure 2). Relative to the smoking areas, nicotine levels were lower in the no-smoking areas in each of the restaurants (Wilcoxon paired sample test, $P = .02$). The median difference was 2.2 $\mu g/m^3$. The Spearman rank correlation of nicotine concentrations in no-smoking and smoking areas was .45.

Considerable variation in respirable suspended particle concentrations was observed among both the no-smoking and smoking sections of the restaurants. In some restaurants, the concentrations of this marker for environmental tobacco smoke were higher in the *no-smoking* sections than in the *smoking* sections of other restaurants. For example, the respirable suspended particle concentrations in the no-smoking sections of restaurants 1 through 3 ranged from 53.9 to 69.0 $\mu g/m^3$, which was higher than the concentrations observed in the smoking sections of restaurants 4 through 7, which ranged from 21.7 to 53.2 $\mu g/m^3$ (Figure 1). Nicotine levels in these restaurants did not follow the same trend (Figure 2), suggesting that sources of respirable suspended particles other than cigarette smoke may be present in restaurants 1 through 3. We noted that in two of these three restaurants, flame servers were used to prepare and warm food at tableside. In one restaurant (restaurant 6), nicotine concentrations in the no-smoking section approached or exceeded the levels measured in the smoking sections of other restaurants. At this restaurant, the sampler in the no-smoking section was within 750 cm (25 ft) of an area where waiters and waitresses smoked.

Discussion

Environmental tobacco smoke is composed of the sidestream smoke from smoldering cigarettes, cigars, and pipes

and the exhaled portion of mainstream smoke. It is a complex mixture of aerosols and vapors and hundreds of chemical compounds. Two markers, respirable suspended particles and nicotine, have been used frequently to quantify environmental tobacco smoke concentrations.[4,5] Respirable particles are classified as particulate matter of less than 2.5 μm aerodynamic diameter. Particles of this size range are too small to be filtered out by the upper respiratory tract and may be inhaled into the lung. In indoor environments in the United States, a major source of respirable suspended particles is cigarette smoke.[6] In restaurants, cooking operations may represent another prominent source of respirable suspended particles. Nicotine occurs in the vapor phase of environmental tobacco smoke and is a highly specific marker of tobacco smoke.[4,5]

Our measurements of respirable suspended particles and nicotine in restaurants indicate that confining tobacco smoking to designated seating sections is an effective way to reduce, although not to eliminate, the exposures of nonsmokers. The pattern of consistently lower levels of respirable suspended particles and nicotine in the no-smoking relative to the smoking areas indicates that the Albuquerque ordinance can be effective in restaurants, regardless of how the individual restaurant management may choose to implement the policy. The greatest protection was afforded by seating arrangements in which a wall or partition physically segregated smokers from nonsmokers (Figures 1 and 2: restaurant 2). But even for floor plans that basically involved one large room (e.g., restaurant 4), substantial protection of the air of nonsmokers was still observed.

To date, the available information comparing concentrations of environmental tobacco smoke components in smoking and no-smoking areas is limited. Repace and Lowrey[7] used a piezoelectric balance to characterize the ranges of respirable suspended particle concentrations in various indoor environments, including the smoking and no-smoking areas of two sandwich restaurants. In one restaurant at lunchtime, respirable suspended particle concentrations in smoking and no-smoking areas averaged 86 and 51 $\mu g/m^3$, respectively. In a second restaurant in the evening, respirable suspended particle concentrations in the smoking and no-smoking areas averaged 110 and 55 $\mu g/m^3$, respectively. These concentrations are comparable to our findings.

Another study[8] compared carbon monoxide concentrations in the no-smoking and smoking sections of a bingo game room. Similar levels of carbon monoxide, approximately 10 ppm, were measured in the two sections. Nonsmoking subjects who sat in the no-smoking and smoking sections for 3 hours had similar carbon monoxide concentrations in end-expired breath samples. However, the conditions in this particular setting, a large single room in which only 20% of the seating was designated as no-smoking, differ considerably from those in the restaurants sampled in our study. In the bingo game room, nonsmokers appear to have been placed close to smokers, so that the protective effect of separation was lost.

It is important to recognize that the reduction of environmental tobacco smoke concentrations we observed in no-smoking as compared with smoking sections, although substantial, was not complete. In fact, concentrations of nicotine were as high in no-smoking sections of some restaurants as in smoking sections of others. Thus, people who sit in no-smoking sections are still exposed to respirable particles and nicotine vapor generated by smoking and to the other components of environmental tobacco smoke that co-occur with these species. Furthermore, restaurant employees, who spend longer periods of time in restaurants than do the patrons, will still be exposed to environmental tobacco smoke in no-smoking areas. These findings are consistent with the conclusion of the 1986 report of the US surgeon general that "the simple separation of smokers and nonsmokers may reduce, but does not eliminate, the exposure of nonsmokers to environmental tobacco smoke."[5]

The measurements made in this study were included in a television news story that also contained descriptions of the experiences of other cities that have restricted smoking and the potential impacts of environmental tobacco smoke on health. In addition, the results were presented at a public hearing in November 1989 on renewal of the city ordinance, where the city council used the findings in evaluating the efficacy of the regulation. The council voted to maintain, and not to lower, the two thirds to one third ratio for restaurant seating, and the ordinance was renewed without time limits.

The regulations restricting smoking inside public buildings are intended to reduce the exposures of no-smoking people to environmental tobacco smoke, a recognized carcinogen and irritant.[5] The Albuquerque Clean Indoor Air Ordinance is similar to regulations currently in effect in approximately 490 other cities and counties in the United States.[9] In general, these ordinances, like the one in Albuquerque, have been implemented with few problems and at very little cost to local governments, and they are strongly supported by public opinion.[5] While these types of ordinances do not provide perfect protection, our measurements indicate that people sitting in the no-smoking areas of restaurants are exposed to substantially lower concentrations of environmental tobacco smoke than those in smoking areas. A systematic monitoring survey of a representative sample of public places is necessary for a comprehensive evaluation of the policy of establishing no-smoking and smoking areas in public buildings. □

Acknowledgments

We thank the restaurant operators who participated in the study, and Larry Barker and Conroy Chino of KOAT-TV in Albuquerque.

References

1. City of Albuquerque Eighth Council. Albuquerque Clean Indoor Air Ordinance, Council Bill No. F/S 0-128 (November 24, 1989).
2. Marple VA, Rubow KL, Turner W, Spengler JD. Low flow rate sharp cut impactors for indoor air sampling: design and calibration. *J Air Pollut Control Assoc.* 1987;37:1303–1307.
3. Hammond SK, Leaderer BP, Roche AC, Schenker M. Collection and analysis of nicotine as a marker for environmental tobacco smoke. *Atmospheric Environ.* 1987;21:457–462.
4. National Research Council. *Environmental Tobacco Smoke: Measuring Exposures and Assessing Health Effects.* Washington, DC: National Academy Press; 1986.
5. *The Health Consequences of Involuntary Smoking: A Report of the Surgeon General.* Washington, DC: US Dept of Health and Human Services; 1986. DHHS publication CDC 87-8398.
6. Spengler JD, Treitman RD, Tosteson TD, Mage DT, Soczek ML. Personal exposures to respirable particulates and implications for air pollution epidemiology. *Environ Sci Technol.* 1985;19:700–707.
7. Repace JL, Lowrey AH. Indoor air pollution, tobacco smoke, and public health. *Science.* 1980;208:464–472.
8. Olshansky SJ. Is smoker/nonsmoker segregation effective in reducing passive inhalation among nonsmokers? *Am J Public Health.* 1982;72:737–739.
9. Centers for Disease Control. State tobacco prevention and control activities: results of the 1989–1990 Association of State and Territorial Health Officials (ASTHO) Survey final report. *MMWR.* 1991;40(No. RR-11):1–41.