Chapter 4
Prevalence of Exposure to Secondhand Smoke

Introduction *129*

Methods *129*

Metrics of Secondhand Smoke Exposure *130*

Questionnaires *130*
Airborne Concentrations *131*
Biomarkers *131*

Estimates of Exposure *132*

National Trends in Biomarkers of Exposure *132*
Environmental Sites of Exposure *135*
Exposure in the Home *137*
  Representative Surveys of Children *137*
  Representative Surveys of Adults *138*
  Susceptible Populations *139*
  Measurements of Airborne Tracers in Homes *140*
Exposure in the Workplace *141*
  Surveys of Workplaces with Policies Regarding Smoking *141*
  Workplace Surveys *143*
Exposure in Public Places *145*
  Restaurants, Cafeterias, and Bars *145*
  Other Locations *154*
Special Populations *154*
  Prisoners *154*
Evidence Synthesis *154*

Conclusions *158*

Overall Implications *158*

References *159*

Introduction

The 1986 U.S. Surgeon General's report, *The Health Consequences of Involuntary Smoking*, outlined the need for valid and reliable methods to more accurately determine and assess the health consequences of exposure to secondhand smoke (U.S. Department of Health and Human Services [USDHHS] 1986). The report concluded that reliable methods were necessary to research the health effects and to characterize the public health impact of exposure to secondhand tobacco smoke in the home, at work, and in other environments. The report noted that without valid and reliable evidence, policymakers could not draft and implement effective policies to reduce and eliminate exposures: "Validated questionnaires are needed for the assessment of recent and remote exposure to environmental tobacco smoke in the home, workplace, and other environments" (USDHHS 1986, p. 14).

Since the publication of that report, public health investigators have made significant advances in the development and application of reliable and valid research methods to assess exposure to secondhand smoke (Jaakkola and Samet 1999; Samet and Wang 2000). Several investigators have recently developed new methods to measure tobacco smoke concentrations in indoor environments and have discovered sensitive biologic markers of active and involuntary exposures (Jaakkola and Samet 1999; Samet and Wang 2000). These advances have generated a substantial amount of data on exposure of nonsmokers to secondhand smoke and have improved the capability of researchers to measure a recent exposure. However, many public health investigators agree that more accurate tools are still needed to measure temporally remote exposures, which, by necessity, are still assessed using questionnaires (Jaakkola and Samet 1999).

The main methods researchers rely on to evaluate secondhand smoke exposure are questionnaires, measurements of concentrations of the airborne components of secondhand smoke, and measurements of biomarkers (Chapter 3, Assessment of Exposure to Secondhand Smoke). The discussion that follows on the prevalence of secondhand smoke exposure includes current metrics of exposure, changes in exposure over time, exposure of special populations such as children with asthma and persons in prisons, and international differences in exposure.

Methods

To identify research publications on biomarkers of secondhand smoke, the authors of this chapter reviewed the published literature for studies on population exposures to and concentrations of secondhand smoke in different environments by conducting a Medline search with the following terms: tobacco smoke pollution, environmental tobacco smoke, and secondhand smoke. These terms were then paired with the term population or survey. The authors then reviewed abstracts of articles to specifically identify studies that used representative surveys of the U.S. population for inclusion in this report.

To specifically identify articles on concentrations of secondhand smoke, the authors used Boolean logic to search Medline and Web of Science, pairing the selected terms for secondhand smoke (secondhand smoke, environmental tobacco smoke, passive smoking, and involuntary smoking) with terms indicative of a location that included home, work, workplace, occupation and restaurants, bars, public places, sports, transportation, buses, trains, cars, airplanes, casinos, bingo, nightclubs, prisons, correctional institutions, nursing homes, and mental institutions. The authors searched for these terms with and without other selected terms such as exposure, concentration, and level of exposure. The authors also included data from a review of studies on the composition and measurement of secondhand smoke (Jenkins et al. 2000).

This chapter focuses on measured concentrations of airborne nicotine—nicotine is a specific tracer for secondhand smoke and has therefore been widely used in many studies. This discussion also focuses on biomarker levels of cotinine, the metabolite of nicotine. Thus, the abstracts of articles identified through the literature search were further reviewed for data that contained measured values of nicotine in the air of selected environments.

Metrics of Secondhand Smoke Exposure

This chapter considers how researchers have used the techniques for assessing exposure to secondhand smoke to determine the extent of exposure among populations. The discussion includes the strengths and limitations of these techniques.

Questionnaires

A questionnaire-based assessment of exposure to secondhand smoke is the most widely used method to evaluate an exposure. Questionnaires have important advantages: they are relatively inexpensive; they can be feasibly administered in a variety of ways, including mail surveys, telephone surveys, or in person; and they are able to assess both current and past exposures (Jaakkola and Jaakkola 1997; Jaakkola and Samet 1999). The disadvantages include difficulties in validation, particularly of a past exposure, and the potential for misclassification. Misclassification may result from a respondent's lack of knowledge about a current or past exposure, the difficulty in characterizing an exposure in complex indoor environments, and biased recall, whether intentional or unintentional (USDHHS 1986).

Investigators have developed numerous questionnaires that assess exposures to secondhand smoke. The questionnaires address fundamental factors such as duration, source strength (the number of smokers or number of cigarettes smoked), room size, and distance from smokers, as well as the perception of an exposure such as observations of tobacco smoke, odor, and irritation. For example, the indirect index of being married to a smoker or of being in the presence of smokers has been widely used to examine the long-term effects of secondhand smoke exposure (Hirayama 1984; Sandler et al. 1989). However, a misclassification of total exposure may occur with indirect measures because they do not capture exposures outside of the home, and because some smokers may not smoke in the house. Nevertheless, compared with persons living in smoke-free homes, Hammond (1999) demonstrated that persons who are married to or living with smokers have higher exposures to secondhand smoke.

Several investigators have used questionnaires to quantitatively estimate exposures by ascertaining the number of hours per day of exposure and the number of cigarettes smoked in a specific location, such as in the home, at work, or in public places (Coghlin et al. 1989; Fontham et al. 1994; Pirkle et al. 1996). These estimates may be made either collectively or separately in each location where the respondents spend time. Although it may be necessary to ask many questions to cover all possible microenvironments of exposure, questionnaires that capture objective measures may provide more accurate estimates of an exposure, and measured concentrations of airborne components of secondhand smoke can be used to calculate summary measures across exposure locations.

Studies have assessed secondhand smoke exposure by asking respondents to rate their perceived level of exposure (e.g., none, slight, moderate, heavy) in various environments (Haley et al. 1989). However, this type of assessment cannot be readily standardized and could potentially result in both random and nonrandom misclassification. For example, persons with a respiratory disease such as asthma may be more likely to perceive exposures to secondhand smoke and to classify them toward the higher end of the scale.

Questionnaires are the only means of assessing remote past exposures to secondhand smoke, absent stored samples for biomarker measurements. For example, Sandler and colleagues (1989) used the smoking status of the spouse as a surrogate for determining household exposures to secondhand smoke. These researchers found that 30 percent of nonsmoking men and 64 percent of nonsmoking women in Washington County, Maryland, reported an exposure in 1963. This

information was used to assign an exposure in assessing subsequent disease risk. In a community-based study in California, 60 percent of nonsmoking participants reported secondhand smoke exposure during their lifetime, defined as at least one hour per day for at least one year (Berglund et al. 1999). However, biomarker data from other studies indicate higher percentages for secondhand smoke exposure. Data from the Third National Health and Nutrition Examination Survey (NHANES III) showed a detectable level of cotinine in 88 percent of nonsmoking adults (Pirkle et al. 1996).

Many investigators have validated questionnaire assessments of current exposures to secondhand smoke using biomarkers, specifically cotinine (Haley et al. 1989; Jarvis et al. 1991; Hammond et al. 1993; Pirkle et al. 1996; Al-Delaimy et al. 2000; Mannino et al. 2001). These studies have demonstrated that persons who were classified as having high levels of secondhand smoke exposure (often defined as living with a smoker) had higher levels of biomarkers in biologic samples of serum, urine, saliva, or hair when compared with persons who had low levels of exposure (often defined as not living with a smoker). Because there is no known biomarker that assesses long-term or temporally remote exposures, researchers still use questionnaires. For example, Coghlin and colleagues (1989) evaluated the reliability of a questionnaire and a personal diary by measuring the individual exposure of each study participant during a one-week period. The questionnaire and the personal diary were both used to collect information on the number of smokers the participants were exposed to, and the proximity and duration of exposure. The investigators found a high correlation (r^2 [prediction values] = 0.98) between the exposure score derived from data recorded in the personal diaries and the log of nicotine concentrations (r^2 measures the strength of the linear model that was used).

Airborne Concentrations

Measuring airborne concentrations of secondhand smoke constituents provides estimates of the level of an exposure and identifies the environments in which the exposure occurred. These measurements can be made using personal monitors, a form of assessing direct exposures (Hammond et al. 1987, 1988, 1993; Coghlin et al. 1989; Mattson et al. 1989; Kado et al. 1991; Emmons et al. 1994; Jenkins et al. 1996a), or monitors that evaluate the concentrations in various microenvironments, a form of assessing indirect exposures (Henderson et al. 1989; Leaderer and Hammond 1991; Marbury et al. 1993; Hammond 1999). Measurements of airborne contaminants can also evaluate the efficacy of various control measures (Vaughan and Hammond 1990; Hammond et al. 1995; Emmons et al. 2001; Hammond 2002). Concentrations are typically assessed by measuring specific components of secondhand smoke referred to as tracers.

Studies have used several airborne constituents of tobacco as tracers, and their advantages and disadvantages are reviewed in Chapter 3 (Assessment of Exposure to Secondhand Smoke) of this report. As noted in that chapter, the concentration of secondhand smoke in any given location will depend on the number of cigarettes smoked in that location, the size of the room, the exchange of air in that room with outdoor air (whether windows are open, or how much air is circulated by natural means and by mechanical systems), and the interaction of the tobacco smoke with surfaces in the room. Because each of these factors has a range of values across locations, the concentration of secondhand smoke varies across settings. This variation results in a distribution of secondhand smoke concentrations in each type of setting. For example, Rogge and colleagues (1994) found a wider range of concentrations in locations such as workplaces and restaurants than in the home because a wider range exists in the number of smokers, the size of the rooms, and the exchange rates of indoor with outdoor air.

Biomarkers

Biomarkers provide an indicator of the internal dose of secondhand smoke and reflect exposure (Chapter 3, Assessment of Exposure to Secondhand Smoke). Persons with comparable exposures to secondhand smoke can have different levels of a marker because of individual variations in factors that determine uptake, metabolism, and elimination of the biomarker (Pirkle et al. 1996; Jaakkola and Samet 1999). Cotinine is the biomarker most frequently used to measure tobacco smoke doses, including doses from secondhand smoke (Benowitz 1999). Cotinine has a half-life ranging from 7 to 40 hours in adults and 32 to 38 hours in children (Jaakkola and Jaakkola 1997) and can be measured in serum, urine, saliva, hair, and breast milk. Studies show that cotinine measurements separated current active smokers from current nonsmokers with a high degree of validity and were used to identify people with current and high levels of secondhand smoke exposure (Pirkle et al. 1996; Mannino et al. 2001). Given its half-life, investigators

have demonstrated that cotinine levels are generally not influenced by an exposure that occurred more than two to four days before the testing (Benowitz 1996). However, cotinine levels increased in people using nonsmoking-related sources of nicotine, such as nicotine patches or spit tobacco. Other biomarkers of tobacco smoke exposure, such as 4-aminobiphenyl adducts or nitrosamines, have not been widely used in population studies and are not discussed in this chapter (Jaakkola and Samet 1999).

Estimates of Exposure

National Trends in Biomarkers of Exposure

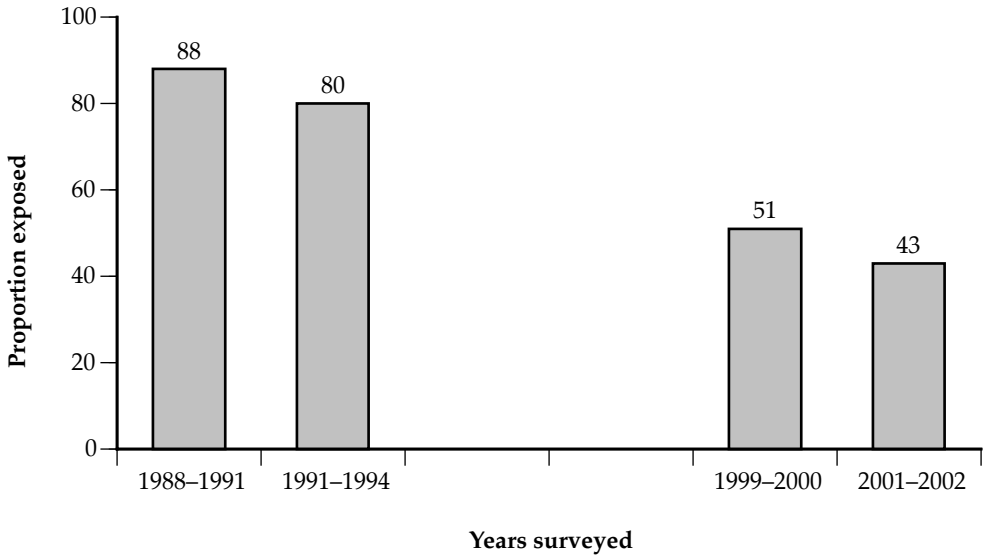
Beginning in 1988, researchers used serum cotinine measurements to assess exposures to secondhand smoke in the United States within the NHANES. The NHANES is conducted by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC), and is designed to examine a nationally representative sample of the U.S. civilian (noninstitutionalized) population based upon a complex, stratified, multistage probability cluster sampling design (see http://www.cdc.gov/nchs/nhanes.htm). The protocols include a home interview followed by a physical examination in a mobile examination center, where blood samples are drawn for serum cotinine analysis. NHANES III, conducted from 1988 to 1994, was the first national survey of secondhand smoke exposure of the entire U.S. population aged 4 through 74 years. There were two phases: Phase I from 1988 to 1991, and Phase II from 1991 to 1994. There were no further studies between 1995 and 1998. In 1999, NCHS resumed NHANES on a continuous basis and completed a new nationally representative sample every two years. This more recent NHANES (1999) also began to draw blood samples for serum cotinine analyses from participants aged three years and older.

Researchers have reported serum cotinine levels in nonsmokers from the NHANES for four distinct intervals within the overall time period of 14 years, from 1988 through 2002: Phase I and Phase II of NHANES III, NHANES 1999–2000, and NHANES 2001–2002 (Pirkle et al. 1996, 2006). Researchers have reported additional data on serum cotinine levels in nonsmokers from NHANES 1999–2002 in the *National Report on Human Exposure to Environmental Chemicals* (CDC 2001a, 2003, 2005). To maintain comparability among survey intervals, trend data are only reported for participants aged four or more years in each study interval (Pirkle et al. 2006). Factors that affect nicotine metabolism, such as age, race, and the level of exposure to secondhand smoke, also influence cotinine levels (Caraballo et al. 1998; Mannino et al. 2001). Because cotinine levels reflect exposures that occurred within two to three days, they represent patterns of usual exposure (Jarvis et al. 1987; Benowitz 1996; Jaakkola and Jaakkola 1997).

Studies document NHANES serum cotinine levels in both children and adult nonsmokers (Pirkle et al. 1996, 2006; CDC 2001a, 2003, 2005). Nonsmoking adults were defined in these studies as persons whose serum cotinine concentrations were 10 nanograms per milliliter (ng/mL) or less, who reported no tobacco or nicotine use in the five days before the mobile examination center visit, and who were self-reported former smokers or lifetime nonsmokers. In NHANES III, the laboratory limit of detection was 0.050 ng/mL. However, the laboratory methods have continued to improve, and the detection limit was recently lowered to 0.015 ng/mL (CDC 2005; Pirkle et al. 2006). Additionally, researchers have categorized serum cotinine concentrations by age, race, and ethnicity. The racial and ethnic categories are non-Hispanic White, non-Hispanic Black, Mexican American, or "Other," and are self-reported. The category of "Other" was included in these reports in mean and percentile estimates for the total population but not in the geometric mean estimates because of small sample sizes (CDC 2005; Pirkle et al. 2006).

Figure 4.1 shows the overall proportion of all nonsmokers aged four or more years with serum cotinine levels of 0.050 ng/mL or greater for the four survey periods. Pirkle and colleagues (1996) reported detectable levels of serum cotinine among nearly all nonsmokers (87.9 percent) during Phase I (1988–1991) of NHANES III. Exposures among nonsmokers have declined significantly since that time

Figure 4.1 Trends in exposure* of nonsmokers† to secondhand smoke in the U.S. population, NHANES‡ 1988–2002



*Serum cotinine ≥0.05 nanograms per milliliter.
†Aged ≥4 years.
‡NHANES = National Health and Nutrition Examination Survey.
Source: Adapted from Pirkle et al. 2006.

(CDC 2005). The proportion of U.S. nonsmokers with cotinine concentrations of 0.050 ng/mL or greater fell to 43 percent in NHANES 2001–2002 (Pirkle et al. 2006).

Pirkle and colleagues (2006) provided additional data on the levels and distribution of serum cotinine concentrations in U.S. nonsmokers during 1988–2002. Trends in the adjusted geometric mean cotinine concentrations (adjusted for age, race, and gender) are in Table 4.1. Since Phase I of NHANES III, secondhand smoke exposures measured by serum cotinine concentrations in U.S. nonsmokers aged four or more years have declined by about 75 percent (from 0.247 ng/mL to 0.061 ng/mL). While declines among children aged 4 through 11 years and young persons aged 12 through 19 years also have been notable, the declines have been smaller than those among adults aged 20 through 74 years. Trends among racial and ethnic categories were also stratified by age: 4 through 11 years, 12 through 19 years, and 20 through 74 years. Pirkle and colleagues (2006) noted that serum cotinine levels in NHANES differed by race and ethnicity. Overall, in the order of the adjusted mean cotinine concentrations during each of the four time periods, concentrations among Mexican Americans were less than those of non-Hispanic Whites, which were less than those of non-Hispanic Blacks; the non-Hispanic Black mean cotinine concentrations were significantly higher during each of the four time periods (Pirkle et al. 2006).

Current patterns of secondhand smoke exposure are reflected in the NHANES 1999–2002 serum cotinine concentrations (Table 4.2). As noted in Figure 4.1, the proportion of U.S. nonsmokers with serum cotinine levels of 0.050 ng/mL or greater has declined since NHANES III to less than 45 percent. However, the proportion of children and nonsmoking adults with serum cotinine levels of 0.050 ng/mL or greater in NHANES 1999–2002 differs significantly by age, from 59.6 percent among children aged 3 through 11 years to 35.7 percent among nonsmoking adults aged 60 through 74 years. Additionally, the median cotinine concentration in the serum is significantly higher in children aged 3 through 11 years (0.09 ng/mL) than in older adults (0.035 ng/mL) (CDC 2005). Children aged 3 through 11 years and

Table 4.1 Trends in serum cotinine levels (nanograms per milliliter) of nonsmokers* stratified by age, gender, race, and ethnicity, United States, 1988–2002

Population		NHANES III, Phase I 1988–1991	NHANES III, Phase II 1991–1994	NHANES 1999–2000	NHANES 2001–2002	% decline from 1988–1991 to 2001–2002
Overall						
Aged ≥4 years	Geometric mean†	0.247	0.182	0.106	0.061	75.3
	95% CI‡	0.219–0.277	0.165–0.202	0.094–0.119	0.049–0.076	
Aged 4–11 years						
Male	Geometric mean	0.283	0.234	0.166	0.098	65.4
	95% CI	0.223–0.360	0.188–0.291	0.105–0.262	0.064–0.151	
Female	Geometric mean	0.328	0.285	0.172	0.115	64.9
	95% CI	0.240–0.449	0.235–0.345	0.113–0.262	0.075–0.177	
Race and ethnicity						
Non-Hispanic White	Geometric mean	0.295	0.255	0.171	0.100	
	95% CI	0.226–0.385	0.214–0.303	0.100–0.293	0.061–0.165	
Non-Hispanic Black	Geometric mean	0.534	0.460	0.284	0.261	
	95% CI	0.387–0.738	0.393–0.538	0.249–0.324	0.188–0.361	
Mexican American	Geometric mean	0.192	0.125	0.080	0.060	
	95% CI	0.148–0.250	0.107–0.145	0.066–0.097	0.042–0.086	
Aged 12–19 years						
Male	Geometric mean	0.346	0.239	0.189	0.090	74.0
	95% CI	0.255–0.470	0.190–0.300	0.138–0.258	0.061–0.132	
Female	Geometric mean	0.280	0.228	0.156	0.078	72.1
	95% CI	0.223–0.353	0.175–0.298	0.124–0.197	0.048–0.126	
Race and ethnicity						
Non-Hispanic White	Geometric mean	0.301	0.219	0.170	0.074	
	95% CI	0.228–0.396	0.174–0.276	0.139–0.210	0.044–0.123	
Non-Hispanic Black	Geometric mean	0.515	0.460	0.263	0.227	
	95% CI	0.392–0.677	0.374–0.567	0.229–0.303	0.191–0.270	
Mexican American	Geometric mean	0.179	0.143	0.095	0.063	
	95% CI	0.139–0.229	0.126–0.162	0.082–0.110	0.045–0.089	

Table 4.1 Continued

Population		NHANES III, Phase I 1988–1991	NHANES III, Phase II 1991–1994	NHANES 1999–2000	NHANES 2001–2002	% decline from 1988–1991 to 2001–2002
Aged ≥20 years						
Male	Geometric mean	0.293	0.199	0.106	0.067	77.1
	95% CI	0.259–0.332	0.178–0.222	0.092–0.122	0.054–0.082	
Female	Geometric mean	0.188	0.138	0.078	0.042	77.7
	95% CI	0.165–0.215	0.120–0.159	0.072–0.085	0.035–0.050	
Race and ethnicity						
Non-Hispanic White	Geometric mean	0.215	0.151	0.085	0.044	
	95% CI	0.189–0.244	0.133–0.172	0.077–0.095	0.036–0.055	
Non-Hispanic Black	Geometric mean	0.401	0.299	0.135	0.129	
	95% CI	0.325–0.494	0.271–0.330	0.116–0.157	0.101–0.163	
Mexican American	Geometric mean	0.204	0.138	0.078	0.058	
	95% CI	0.165–0.251	0.117–0.162	0.066–0.093	0.040–0.083	

*From four National Health and Nutrition Examination Survey (NHANES) study intervals.
†Individuals with serum cotinine levels below the laboratory limit of detection (LOD) were assigned a value of LOD/square root of 2.
‡CI = Confidence interval.
Source: Adapted from Pirkle et al. 2006.

youth aged 12 through 19 years are also significantly more likely than adults to live in a household with at least one smoker. Estimates of the number of secondhand smoke exposures nationwide in 2000 can be extrapolated from national estimates of the proportion of children and nonsmoking adults with measured serum cotinine concentrations of 0.05 ng/mL or greater. Overall, based upon serum cotinine measures, approximately 22 million children aged 3 through 11 years, 18 million nonsmoking youth aged 12 through 19 years, and 86 million nonsmoking adults aged 20 or more years in the United States were exposed to secondhand smoke in 2000 (Table 4.2).

Although the number of children and nonsmoking adults currently exposed to secondhand smoke in the United States remains very large, there have been significant declines in the proportion and mean concentrations of these exposures since 1988. In order to characterize these trends in exposure, data on the principal environments where children and nonsmoking adults are typically exposed to secondhand smoke are reviewed in the discussion that follows.

Environmental Sites of Exposure

The principal places where studies have measured exposures to secondhand smoke represent key microenvironments: homes, worksites, and public places such as restaurants, malls, and bars. The contributions of these different locations to total personal exposures vary across different groups. For example, the dominant site of exposure for children is the home, whereas worksites are typically important exposure locations for nonsmoking adults who may not be exposed at home.

People spend most of their time at home, which is potentially the most important location of secondhand smoke exposure for people who live with regular smokers (Klepeis 1999). Because the workplace is second only to the home as the location where adults spend most of their time, smoking in the workplace has been a major contributor to total secondhand smoke exposure. The National Human Activity Pattern

Table 4.2 Serum cotinine levels among nonsmokers aged 3 years and older, NHANES* 1999–2002

Age group	Median cotinine level (SE†) (95% CI‡)	% with levels ≥0.05 ng/mL§ (SE) (95% CI)	% with at least 1 smoker in the home (SE) (95% CI)	Total population (2000)	Estimated number of persons (in millions) with serum cotinine levels ≥0.05 ng/mL
≥3 years	**<LOD△ (<LOD–0.52)**	**47.0 (1.9) (43.0–50.9)**	**11.1 (0.45) (10.2–12.0)**	**270,005,230**	**126.9**
3–19 years	**0.08 (0.01) (0.06–0.11)**	**57.7 (2.8) (52.0–63.3)**	**22.6 (1.4) (19.9–25.6)**	**69,056,589**	**39.8**
3–11 years	0.09 (0.02) (0.06–0.12)	59.6 (2.9) (53.5–65.4)	24.9 (1.8) (21.5–28.7)	36,697,776	21.9
12–19 years	0.07 (0.01) (0.05–0.10)	55.6 (3.1) (49.1–61.9)	19.9 (1.3) (17.4–22.7)	32,358,813	18.0
≥20 years	**<LOD (<LOD–<LOD)**	**42.8 (1.9) (39.0–46.6)**	**6.56 (0.32) (5.93–7.25)**	**200,948,641**	**86.0**
20–39 years	<LOD (<LOD–0.066)	49.2 (2.9) (43.3–55.2)	6.85 (0.77) (5.43–8.61)	81,562,389	40.1
40–59 years	<LOD (<LOD–<LOD)	41.6 (2.2) (37.1–46.2)	7.3 (0.86) (5.73–9.26)	73,589,052	30.6
≥60 years	<LOD (<LOD–<LOD)	35.7 (1.7) (32.3–39.4)	5.12 (0.52) (4.15–6.3)	45,797,200	16.3

*NHANES = National Health and Nutrition Examination Survey.
†SE = Standard error.
‡CI = Confidence interval.
§ng/mL = Nanograms per milliliter.
△LOD = Limit of detection (0.05 ng/mL).
Sources: U.S. Bureau of the Census 2005; Centers for Disease Control and Prevention, National Center for Health Statistics, unpublished data.

Survey (NHAPS), conducted from 1992 to 1994, interviewed 9,386 randomly chosen U.S. residents about their activities and exposures to secondhand smoke (Klepeis 1999; Klepeis et al. 2001). For those persons reporting secondhand smoke exposure of at least one minute, the average daily duration of the exposure and the percentage of respondents who reported an exposure in each indoor locale were as follows:

- 305 minutes in the home (58 percent);
- 363 minutes in the office or factory (10 percent);
- 249 minutes in schools or public buildings (6 percent);
- 143 minutes in bars or restaurants (23 percent);
- 198 minutes in malls or stores (7 percent);
- 79 minutes in vehicles (33 percent); and
- 255 minutes in other indoor locations (6 percent) (Klepeis 1999).

Even for adults who live in homes where smoking routinely occurs, the workplace can add significantly to this exposure. Among NHANES III participants who lived in smoke-free homes, a workplace that permitted smoking was typically the major contributor to their total secondhand smoke exposure (Pirkle et al. 1996).

Studies have shown that restaurants can be important sites of exposures to children as well as adults (Maskarinec et al. 2000; McMillen et al. 2003; Skeer and Siegel 2003; Siegel et al. 2004), and other public places may also contribute substantially to exposures of selected segments of the population. Finally, persons who cannot move about freely, such as those who live in nursing homes, mental institutions, or correctional facilities, may find such exposures unavoidable.

Exposure in the Home

Secondhand smoke exposure at home can be substantial for both children and adults (Jenkins et al. 1996a; Pirkle et al. 1996; Klepeis 1999; Klepeis et al. 2001). This section considers children exposed to secondhand smoke at home separately from adults who are exposed at home because the patterns are different for the two groups (Mannino et al. 1996, 1997). The definition of "children" varies across the studies cited in this report. There are also separate data for special populations, including children with asthma, pregnant women, and persons living in the inner city.

Representative Surveys of Children

Researchers have conducted a number of local (Greenberg et al. 1989), state (King et al. 1998), and national (Mannino et al. 1996) surveys of childhood exposure to secondhand smoke. One of the best data sources available on children's secondhand smoke exposure in the home is the National Health Interview Survey (NHIS). This information can be derived from NHIS data by correlating data on smoking in the home with data on households with children. NHIS data shows that the proportion of children aged 6 years and younger who are regularly exposed to secondhand smoke in their homes fell from 27 percent in 1994 to 20 percent in 1998. Most surveys were primarily based on the indirect indicator of one or more smoking adults in a home; estimates of the percentages exposed in the home ranged from 54 to 75 percent of the children (Lebowitz and Burrows 1976; Schilling et al. 1977; Ferris et al. 1985). A 1988 survey using an indirect indicator estimated that 48.9 percent of the children studied had experienced postnatal exposures to secondhand smoke (Overpeck and Moss 1991). Exposure prevalence was higher for children in poverty (63.6 percent) or for those whose mothers had less than 12 years of education (66.7 percent). An analysis of National Health Interview Survey (NHIS) data for 1994 showed that 35 percent of U.S. children lived in homes where they had contact with a smoker at least one day per week (Schuster et al. 2002).

Use of the indirect approach assumes that the presence of a smoking adult in the household results in exposure of children to secondhand smoke. Over time, as more people recognized the health effects from exposure in the home and implemented in-home smoking policies, the presence of smoking adults in the home has become a less valid indicator of exposure. In a 1991 survey of U.S. adults, 11.8 percent of current smokers reported that because no smoking had occurred in their homes in the two weeks before the survey, their children had not been exposed to secondhand smoke in the home (Mannino et al. 1996). Using data from the California Tobacco Survey, Gilpin and colleagues (2001) found that the proportion of households prohibiting smoking increased from 50.9 percent in 1993 to 72.8 percent in 1999 (Gilpin et al. 2001). The increase was greater in homes with smokers, from 20.1 percent in 1993 to 47.2 percent in 1999 (Pierce et al. 1998; Gilpin et al. 2001). The survey did not capture data from nonfamily members who may have smoked in the home, nor would it have addressed the contamination of one dwelling from smokers in another within a multiresidence building.

Other analyses have used questionnaires that ask specifically about the number of cigarettes smoked in the home to determine whether children were exposed to secondhand smoke. A 1991 nationally representative survey estimated that 31.2 percent of U.S. children were exposed daily to secondhand smoke in their homes, with an additional 5.8 percent exposed at home at least one day in the previous two weeks (Mannino et al. 1996). This exposure varied significantly by socioeconomic status (SES) (46.5 percent for a lower SES versus 22.5 percent for a higher SES) and by region of the country, with the lowest exposure (24.3 percent) in the western part of the United States (Mannino et al. 1996). In Phase I of the NHANES III (collected from 1988 to 1991), 43 percent of children aged 2 months through 11 years lived in a home with at least one smoker (Pirkle et al. 1996). In NHANES 1999–2002, the proportion of children aged 3 through 11 years living with one or more smokers in the household was 24.9 percent (Table 4.2). However, 59.6 percent of children aged 3 through 11 years had a serum cotinine concentration of 0.05 ng/mL or higher. State and local surveys have documented higher levels of reported exposure. In a 1985 study from New Mexico, 60 to 70 percent of the children had been exposed to secondhand smoke (Coultas et al. 1987). In a 1986 study of North Carolina infants, 56 percent had been exposed (Margolis et al. 1997). On the basis of self-reported data on smoking among household residents, CDC estimated in 1996 that 21.9 percent of U.S. children had been exposed to secondhand smoke in their homes (CDC 1997). The prevalence of exposure varied by state, from a low of 11.7 percent in Utah to a high of 34.2 percent in Kentucky. However, the data on serum cotinine concentrations suggest that these estimates are low.

As noted above, since 1988 the NHANES has provided nationally representative measurements of serum cotinine levels in both children and adults (Pirkle et al. 1996, 2006; CDC 2001a, 2003, 2005). Figure 4.1 and Table 4.1 show overall U.S. trends in exposure measured by serum cotinine concentrations. Although exposures have declined among both children and adults since Phase I of NHANES III (1988–1991), the percentage of the decline was smaller among children aged 4 through 11 years. In the NHANES 2001–2002, mean cotinine levels were highest among children aged 4 through 11 years (non-Hispanic Black

children in particular) (Pirkle et al. 2006). Measured cotinine concentrations were more than twice as high among children aged 4 through 11 years than among nonsmoking adults aged 20 or more years, and the levels of non-Hispanic Black children were two to three times higher than those of non-Hispanic White and Mexican American children. While metabolic factors can also influence cotinine levels (Caraballo et al. 1998; Mannino et al. 2001), the racial and ethnic differences in serum cotinine concentrations overall, and particularly among children, presumably reflect greater exposures to secondhand smoke among non-Hispanic Black populations (Pirkle et al. 2006).

Table 4.2 compares current estimates of national exposure by age. In Phases I and II of NHANES III (1988–1994), 84.7 percent of children aged 4 through 11 years had a serum cotinine concentration of 0.05 ng/mL or greater; 99.1 percent of children with a reported exposure in the home and 75.6 percent of children without any reported exposure had measurable cotinine levels (Mannino et al. 2001). The strongest predictor of cotinine levels in children was the number of cigarettes smoked daily in the home, but other factors were also significant predictors, including race, ethnicity, age of the child, size of the home, and region of the country (Mannino et al. 2001). In the most recent estimates of exposure (Table 4.2), 59.6 percent of children aged 3 through 11 years had a serum cotinine concentration of 0.05 ng/mL or greater, and 24.9 percent reported living with at least one smoker in the household. Based upon this estimate of the proportion of children aged 3 through 11 years living with a smoker in the household, an estimated nine million children or more in this age range may be exposed to secondhand smoke. However, serum cotinine measurements indicate an even greater exposed population of almost 22 million children aged 3 through 11 years in the year 2000.

Trends in exposure of children to secondhand smoke indicate that levels of exposure have declined significantly since Phase I of NHANES III (Pirkle et al. 2006). The multiple factors related to this decline are still being studied. Several researchers have suggested that a major component of this decline is related to the decrease in parental smoking (Shopland et al. 1996) and to the increase in household smoking restrictions (Gilpin et al. 2001). Data from the 1992 and 2000 NHIS (Soliman et al. 2004) indicate that self-reported exposure of nonsmokers to secondhand smoke in homes with children declined significantly in the 1990s from 36 percent in 1992 to 25 percent in 2000. Because researchers have identified parental smoking in the home as a major source for exposure among younger children (Mannino et al. 2001), this decline in reported home exposures to secondhand smoke suggests that voluntary changes in home policies and smoking practices of adults in homes where children reside are a major contributing factor to the observed declines in serum cotinine concentrations among children since Phase I of NHANES III.

Protecting children from secondhand smoke exposure in homes has been the focus of the U.S. Environmental Protection Agency's parental outreach and educational programs to promote smoke-free home rules for the last decade. The potential for exposing children to secondhand smoke has dropped even further as more local and state governments restrict smoking in public areas (CDC 1999). Jarvis and colleagues (2000) documented similar findings in data from Great Britain. From 1988 to 1996, the proportion of homes without smokers increased from 48 to 55 percent. During this same period, the geometric mean salivary cotinine levels decreased from 0.47 to 0.28 ng/mL among children with nonsmoking parents, and from 3.08 to 2.25 ng/mL among children with two smoking parents (Jarvis et al. 2000).

Additional studies that document exposure of children in the United States to secondhand smoke in the home include three studies that reported the presence of some form of smoking ban at home in many households (Norman et al. 1999; Kegler and Malcoe 2002; McMillen et al. 2003). Norman and colleagues (1999) surveyed a representative sample of 6,985 California adults. Kegler and Malcoe (2002) studied 380 rural, low-income Native American and White parents from northeastern Oklahoma. McMillan and colleagues (2003) conducted a telephone survey of more than 4,500 eligible adults across the United States. Two other studies also focused on prevalence and patterns of childhood household secondhand smoke exposure in the United States: CDC (2001b) reported on the Behavioral Risk Factor Surveillance System (BRFSS) telephone interviews that took place in 20 states, and Schuster and colleagues (2002) reported on personal interviews with 45,335 respondents from around the country in the 1994 NHIS.

Representative Surveys of Adults

Representative surveys of adult household exposures to secondhand smoke in the United States were conducted at the national, state, and local levels to determine the prevalence of exposure in the home (Mannino et al. 1997; King et al. 1998). When analyzing these surveys, researchers need to consider that some current smokers may misclassify

themselves as lifetime nonsmokers or as former smokers (Haley et al. 1983; Coultas et al. 1988). Exposures at home were assessed using questionnaires and cotinine levels. In a California study that was conducted from 1979 to 1980, 24 percent of 37,881 adult lifetime nonsmokers and former smokers reported household exposures (Friedman et al. 1983). When data from Phase I of NHANES III (1988–1991) were analyzed, Pirkle and colleagues (1996) showed that 17.4 percent of nonsmokers reported exposures to secondhand smoke in the home. Mannino and colleagues (1997) reported similar findings when they analyzed data from another national survey that was conducted in 1991: 16.4 percent of lifetime nonsmokers and 19.2 percent of former smokers reported exposures in the home. In findings similar to those among children, there is also evidence that certain subgroups of adults are more likely to be exposed to secondhand smoke. For example, in a 1985–1986 study of 4,200 persons in Philadelphia, an industrialized and urban population, 60 percent reported household exposures (Dayal et al. 1994).

Table 4.1 shows trends in exposure among U.S. nonsmoking adults aged 20 or more years measured by serum cotinine levels. Among all adults in this age group, the geometric mean serum cotinine concentration declined more than 77 percent between Phase I of NHANES III (1988–1991) and NHANES 2001–2002: from 0.293 to 0.067 ng/mL among men and from 0.188 to 0.042 ng/mL among women. Analyses indicate that serum cotinine levels of adult nonsmokers were higher among adults who reported exposures at home or in the workplace (Pirkle et al. 1996). Recent data from NHANES 1999–2002 (CDC, NCHS, unpublished data) indicate that among younger nonsmoking adults aged 20 through 39 years, the proportion who reported living with at least one smoker is much lower (6.9 percent) compared with nonsmoking adults aged 20 through 39 years with a current job who reported that they could smell smoke at work (13.2 percent). However, among older nonsmoking adults aged 40 through 59 years, the proportion who reported living with a smoker (7.3 percent) was similar to the proportion of nonsmoking adults aged 40 through 59 years with a current job who reported smelling smoke at work (9.8 percent). Finally, while older nonsmoking adults reported a slightly lower portion of nonsmokers living with at least one smoker (5.1 percent), a significantly lower proportion of that age group with a current job reported smelling smoke at work (2.0 percent). Thus, particularly for adults aged 20 through 59 years, the worksite remains an important environment for exposure to secondhand smoke.

Susceptible Populations

Some populations may be particularly susceptible to secondhand smoke exposure. Examples include persons with asthma or other chronic respiratory diseases, and fetuses exposed to tobacco smoke components in utero either by maternal smoking or maternal exposure to secondhand smoke. In one 1994 community-based study in Seattle, 31 percent of children with asthma reported household exposures to secondhand smoke, but only 17 percent of children without asthma reported an exposure (Maier et al. 1997).

Studies have tracked smoking by pregnant women using several different data collection systems including natality surveys, NHIS, BRFSS, National Survey of Family Growth, and since 1989, birth certificates in nearly all states and the District of Columbia (CDC 2001a). The estimates from these different sources generally agree that the proportion of women who report smoking during pregnancy has decreased in recent years, from between 30 and 40 percent in the early 1980s to between 10 and 15 percent in the late 1990s. By 2003, only an estimated 10.7 percent of mothers of a live-born infant reported smoking during pregnancy. However, the prevalence of reported smoking was not uniform across all population groups or education levels. For example, a CDC report (CDC 2005) documented that 18 percent of American Indian or Alaska Native women reported smoking during pregnancy, but only 3 percent of Hispanic women reported smoking during pregnancy. And women with 9 to 11 years of education were far more likely to report smoking (25.5 percent) compared with women with 16 or more years of education (1.6 percent) (CDC 2005). Ebrahim and colleagues (2000) showed that the declining trend in smoking during pregnancy in recent years is primarily attributable to a decrease in smoking prevalence among women of childbearing age, rather than to an increase in smoking cessation during pregnancy. Of the women who reported smoking during pregnancy, most (68.6 percent) said that they had smoked 10 or fewer cigarettes daily.

Researchers have also found that pregnant women may conceal their smoking from clinicians (Windsor et al. 1993; Ford et al. 1997). Thus, smoking during pregnancy may be underestimated. Estimates of the prevalence of smoking during pregnancy are also sensitive to how smoking was defined in a study, which may range from any smoking at any time during pregnancy to smoking during the final three months of pregnancy.

Complicating the interpretation of findings on health effects of secondhand smoke exposure in very young children is evidence that a large proportion of children are exposed both prenatally and postnatally. Overpeck and Moss (1991) used CDC data to show that 96 percent of children with prenatal exposures also had postnatal exposures. The investigators found that 29 percent of the children had been exposed prenatally to maternal smoking and that an additional 21 percent had been exposed to secondhand smoke postnatally. A second source of involuntary smoking for a developing fetus is the exposure of a pregnant woman to secondhand smoke. The factors that predicted prenatal maternal exposure to secondhand smoke were similar to those associated with secondhand smoke exposure in general, such as low SES, low levels of education, and living in a small home (Overpeck and Moss 1991).

Although national surveys have not specifically asked about secondhand smoke exposure during pregnancy, they have provided estimates of exposure among women of childbearing age. In NHANES III, 18 percent of nonsmoking females aged 17 years and older reported exposures to secondhand smoke. However, the percentages of reported exposures were higher among women of childbearing age: 31 percent for 17- through 19-year-olds, 30 percent for 20- through 29-year-olds, and 26 percent for 30- through 39-year-olds (Pirkle et al. 1996). Of the nontobacco users surveyed in 1988–1991, 88 percent had detectable levels of serum cotinine (>0.050 ng/mL), a finding that suggests an unreported or unknown exposure. These findings are consistent with results from a 1985 study of 1,231 nonsmoking pregnant women in Maine, which found that 70 percent of the participants had cotinine levels above 0.5 ng/mL (Haddow et al. 1987).

Measurements of Airborne Tracers in Homes

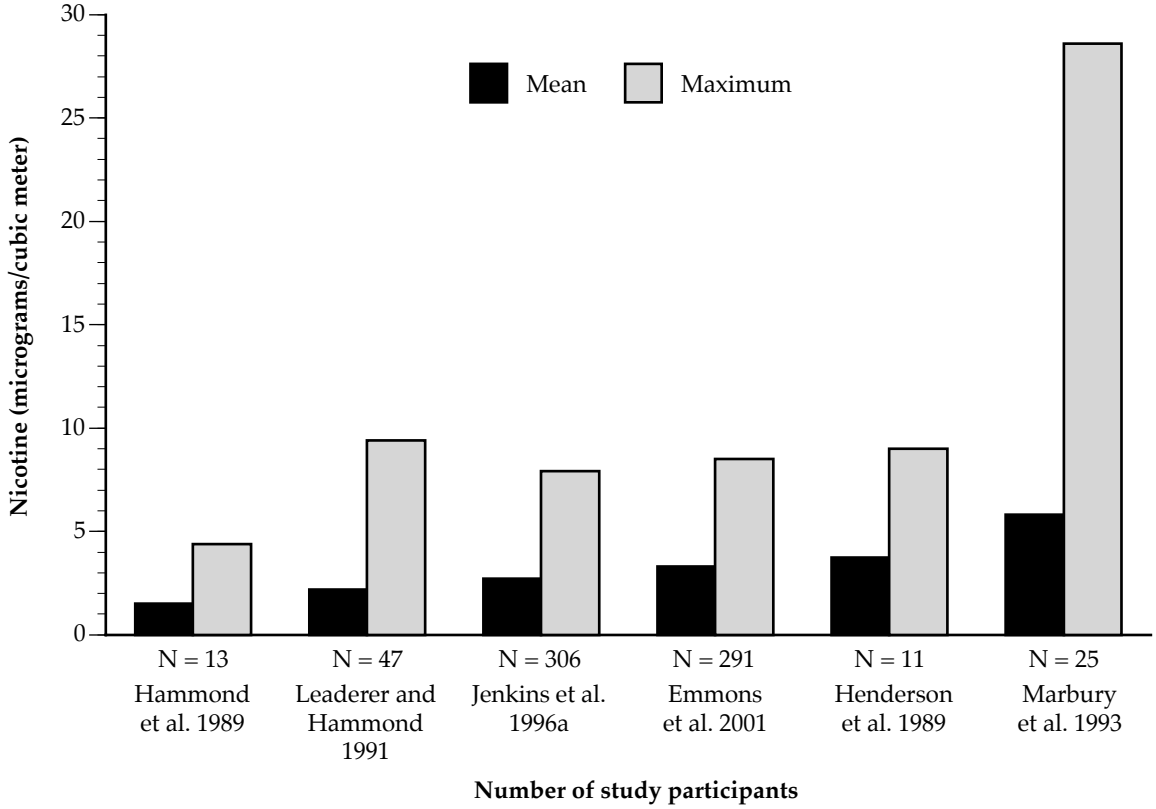
Numerous studies have measured secondhand smoke concentrations in homes (Leaderer and Hammond 1991; Hammond et al. 1993; Marbury et al. 1993; Manning et al. 1994; O'Connor et al. 1995; Jenkins et al. 1996a,b; Phillips et al. 1996, 1997a,b, 1998a–h, 1999a,b). Concentrations of secondhand smoke components are higher at the time that the cigarettes are smoked compared with a few hours later. Measurements taken only during periods of smoking document higher concentrations than samples measured during both smoking and nonsmoking periods. For example, Muramatsu and colleagues (1984) measured both nicotine and particulate matter sequentially for 10 hours in an office. They found that the 30-minute nicotine samples ranged from 2 to 26 micrograms per cubic meter ($\mu g/m^3$) during the workday; most values ranged between 5 and 15 $\mu g/m^3$. The 10-hour averaged concentration was 10 $\mu g/m^3$, which was based on a shorter time period than that used by other studies to obtain stable estimates. Most studies have measured concentrations averaged over longer periods of time, which include periods with and without smoking.

Studies have demonstrated a high correlation (Spearman rho correlation coefficient = 0.74, $p < 0.001$) between nicotine concentrations measured in the family activity rooms and in the kitchens (Emmons et al. 2001), as well as between concentrations in the activity rooms and in the bedrooms (Spearman correlation coefficient = 0.91; 0.90 for homes of smokers only) (Marbury et al. 1993).

The results of several studies that measured nicotine concentrations in the homes of smokers in the United States are presented in Figure 4.2 and Table 4.3. Median nicotine concentrations were generally between 1 and 3 $\mu g/m^3$ (averaged over 14 hours to several weeks), with nicotine concentrations ranging from <0.1 to 8 $\mu g/m^3$ across the span from minimum to the 95th percentile. An exception was a study of 291 low-income homes in New England that found 4 homes with concentrations above 18 $\mu g/m^3$ (Emmons et al. 2001). Homes where smoking was restricted to the basement or the outdoors had lower mean nicotine concentrations of 0.3 $\mu g/m^3$ (Marbury et al. 1993).

Personal sampling of secondhand smoke exposure has yielded similar results with measured home exposure. In a study of exposure away from work (predominantly at home, lasting 16 hours), 306 nonsmokers who reported secondhand smoke exposure had a mean nicotine exposure of 2.7 $\mu g/m^3$ (median 1.2 $\mu g/m^3$), with a 95th percentile value of 7.9 in 1993 and 1994 (Jenkins et al. 1996a). Personal sampling of 100 people in Massachusetts during 1987 and 1988 found the median of a weekly average of nicotine concentrations to be 1.0 $\mu g/m^3$ for nonsmokers married to nonsmokers and 3.5 $\mu g/m^3$ for those married to smokers; the respective maximum values were 9.5 and 14 $\mu g/m^3$. These values included all exposures throughout the week in homes, workplaces, and public places (Coghlin et al. 1989, 1991). To evaluate secondhand smoke exposure among pregnant women, participants in two studies wore passive samplers (small personal monitors that measure secondhand smoke exposure) for one week. Although the two studies had similar designs, the investigators reported quite different results. Among 36 low-income pregnant women in Massachusetts, 80 percent were exposed to

Figure 4.2 Concentrations of nicotine in homes of U.S. smokers



Note: Data are provided in detail in Table 4.3.

nicotine at 0.5 $\mu g/m^3$ or greater, and 25 percent were exposed at a concentration above 2.0 $\mu g/m^3$ (Hammond et al. 1993). The measured exposure was lower for 131 pregnant upper-middle-class women in Connecticut who reported secondhand smoke exposure, with a median of 0.1 $\mu g/m^3$ and a 90th percentile of 0.6 $\mu g/m^3$ (O'Connor et al. 1995).

International studies of secondhand smoke exposure sponsored by the tobacco industry (Jenkins et al. 1996a; Phillips et al. 1996, 1997a,b, 1998a–h, 1999a,b) followed a similar protocol where participants wore a sampling device for 16 to 24 hours. Figure 4.3 illustrates the median nicotine concentrations observed "away from work" (predominantly at home) in the United States compared with homes in Australia and in several European and Asian locations. U.S. homes had the second highest reported values after Beijing, which reported a median of 1.3 $\mu g/m^3$. Hong Kong homes reported 0.3 $\mu g/m^3$, which was consistent with a study of 300 Chinese homes in 18 provinces that reported a 0.1 $\mu g/m^3$ weekly average concentration of nicotine in the homes of smokers (Hammond 1999).

Exposure in the Workplace

This section reviews studies that measured secondhand smoke exposure in the workplace, an important source of secondhand smoke exposure for nonsmoking adults (Klepeis 1999; Klepeis et al. 2001). These studies include surveys, biomarkers (Pirkle et al. 1996), or (more commonly) measurements of airborne nicotine (Vaughan and Hammond 1990; Hammond et al. 1995; Jenkins et al. 1996a; Hammond 1999).

Surveys of Workplaces with Policies Regarding Smoking

Large representative surveys of secondhand smoke workplace exposure have looked at patterns of exposure and the impact of policies to reduce

Table 4.3 Concentrations of nicotine in homes of U.S. smokers

Study	Population Year sampled	Measurement duration	Number of study participants
Hammond et al. 1989	North Carolina 1988	Weekly	13
Henderson et al. 1989	Lower income North Carolina 1987	14 hours	11
Leaderer and Hammond 1991	Randomly chosen New York 1986	1 week (winter)	47
Marbury et al. 1993	Children aged <2 years Living room and bedroom Minnesota 1989	1 week†	25
Jenkins et al. 1996a	Adults Personal sampling 16 cities	16 hours	306
Emmons et al. 2001	Lower income Massachusetts 1997–1998	Weekly	291

*NR = Data were not reported.
† Following the initial measure of exposure, measures were taken weekly for 8 weeks.

exposure. Although not all workplaces are smoke-free, policies toward smoking in workplace settings have changed dramatically since the publication of the 1986 Surgeon General's report (USDHHS 1986). For example, using data from the California Tobacco Survey, Gilpin and colleagues (2001) showed that the percentage of indoor workers in California who reported smoke-free workplaces had increased from 35 percent in 1990 to 93 percent in 1999. Shopland and colleagues (2001) analyzed data from the national Current Population Survey (CPS), a monthly survey of about 50,000 households conducted by the Bureau of the Census for the Bureau of Labor Statistics, and found that the proportion of workers who reported a smoke-free workplace policy had increased from 46 percent in 1993 to 69 percent in 1999. The 1999 data documented a low of 49 percent in Nevada and a high of 84 percent in Utah (Shopland et al. 2001). In an analysis of the 1993 CPS data, Farrelly and colleagues (1999) noted that the proportion of workers in smoke-free worksites also varied by industry, from a low of 30 percent in wholesale or retail trades to 73 percent in medical services. A similar analysis of the 1996 CPS data showed that the proportion of smoke-free worksites ranged from a low of 44 percent in agriculture, forestry, fishing, mining, and construction to 82 percent in professional and related services (Sweeney et al. 2000).

However, having a smoke-free policy in the workplace does not assure workers that they will not be exposed to secondhand smoke. In a 1990 study from California, 9.3 percent of nonsmokers who worked in a "smoke-free" worksite reported at least one episode of exposure at work during the two weeks before the survey (Borland et al. 1992). This proportion was higher at 51 percent among nonsmokers working in sites without a smoking policy (Brancker 1990). In data from Phase I of NHANES III (1988–1991), 47.7 percent of adult nontobacco users who currently worked reported exposures at home or at the worksite (Pirkle et al. 1996). Nonsmoking workers who reported workplace exposures had higher geometric

Concentrations of nicotine (micrograms per cubic meter [$\mu g/m^3$])								
	Geometric mean	Standard deviation	Median	25th percentile	90th percentile	95th percentile	Minimum	Maximum
	1.5	1.1	1.4	NR*	NR	NR	1.1	4.4
	3.74	0.5	3.6	NR	NR	7.5	0.8	9.0
	2.2	2.4	1.0	0.2	8.0	8.5	<0.1	9.4
Living room	5.8	NR	3.0	NR	NR	9.0	0.1	28.6
Bedroom	2.7	NR	2.1	NR	NR	NR	NR	7.2
	2.7	NR	1.2	NR	NR	7.9	NR	NR
	3.3	5.0	1.6	0.3	8.5	10.4	0.3	45.1

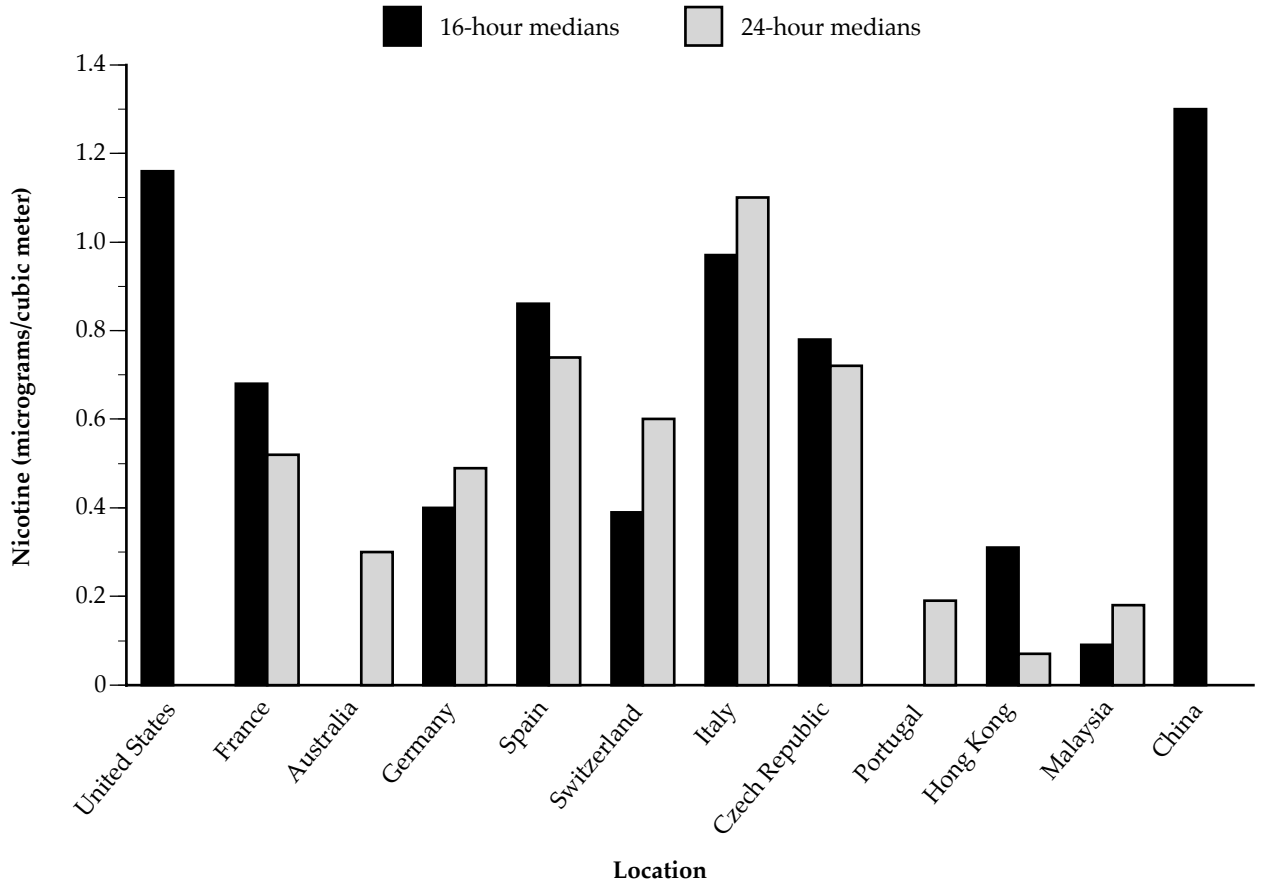
mean levels of cotinine (0.32 ng/mL) compared with workers who did not report workplace or home exposures (0.13 ng/mL) (Pirkle et al. 1996). Recent data suggest that worksite exposures may be declining significantly since Phase I of NHANES III (1988–1991). In NHANES 1999–2002, the proportion of adults aged 20 or more years with a current job who reported smelling smoke at work was 8.94 percent (95 percent CI, 7.84–10.10) (CDC, NCHS, unpublished data).

Workplace Surveys

Hammond (1999) reviewed studies of exposures to secondhand smoke among U.S. workers. The earliest personal sampling of workplace secondhand smoke exposure involved railroad workers studied between 1981 and 1984. Investigators collected more than 625 nicotine samples from participants wearing personal samplers at four railroad locations (Hammond et al. 1988; Schenker et al. 1990). In 1983 and 1984, 275 personal samples were collected and levels were analyzed by job type; 84 samples were collected from smokers and 191 from nonsmokers (Schenker et al. 1986, 1992; Hammond 1999). Among workers such as clerks and brakers who worked in small spaces, nonsmokers and smokers were exposed to similar levels of nicotine. For workers in other types of jobs (notably the repair shop workers), exposure was lower by more than an order of magnitude, possibly because of the large open space and ventilation of the shop. The range of nicotine exposure at work was notably greater among the nonsmoking railroad workers compared with exposures at home; minimum concentration values for all job categories were less than 0.1 $\mu g/m^3$ and maximum values ranged up to 38 $\mu g/m^3$. Half of the nonsmoking workers were exposed to more than 1 $\mu g/m^3$ on at least one sampling day.

Many investigators have studied offices in the United States. Where smoking was allowed, there was a wide range of nicotine concentrations, from less than

Figure 4.3 Concentrations of nicotine away from work in 12 locations



Sources: Jenkins et al. 1996a; Phillips et al. 1996, 1997a,b, 1998a–h, 1999a,b.

0.05 $\mu g/m^3$ to about 70 $\mu g/m^3$ (Table 4.4). For nearly half of the offices, the minimum value was more than 1 $\mu g/m^3$. For offices where five or more samples were collected, median values were between 1 and 17 $\mu g/m^3$, and average values were between 2 and 24.8 $\mu g/m^3$. Most worksites had at least one sample above 10 $\mu g/m^3$, and many studies reported concentrations greater than 40 $\mu g/m^3$.

Offices at worksites that restricted smoking to designated areas generally had much lower concentrations of nicotine (Table 4.4 and Figure 4.4). Half of these worksites had a median concentration of less than 1 $\mu g/m^3$, and only one site (Newspaper A) exceeded 2.5 $\mu g/m^3$. The maximum concentrations in five out of eight workplaces were 1 to 2 $\mu g/m^3$, but in the other three the maximum concentrations were 6.3, 13.7, and 16.7 $\mu g/m^3$. Workplaces with smoking bans had much lower concentrations, with the medians and averages at all worksites less than 1 $\mu g/m^3$, except for one worksite, the weapons systems worksite that had a mean of 2.8 $\mu g/m^3$. The maximum concentrations at three of these worksites were less than 1 $\mu g/m^3$; the maximum concentrations for the other three were 1.9, 2.4, and 8.5 $\mu g/m^3$. In one workplace, lower secondhand smoke concentrations were observed at the same location comparing measurements taken before and after smoking was restricted. Concentrations had declined by more than 90 percent as a result of restricting smoking (Vaughan and Hammond 1990). Thus, workplace policies decrease nicotine concentrations substantially but do not completely eliminate them. These results are consistent with questionnaire survey results cited above, where 9.3 percent of nonsmoking California workers in "smoke-free worksites" reported some secondhand smoke exposure.

A number of studies have measured the nicotine concentrations in a variety of other workplaces, including fire stations and manufacturing, printing, and medical facilities (Table 4.5). Although concentrations were lower in these settings than in offices, the results of the analyses showed that one-third of the workplaces that allowed smoking still had minimum values above 1 $\mu g/m^3$, and most workplaces had detectable levels of nicotine on all of the collected samples (Table 4.5). Two workplaces had maximum values above 50 $\mu g/m^3$, and most had at least one sample above 10 $\mu g/m^3$. Most of the median values were between 1 and 4 $\mu g/m^3$. Where smoking was restricted, the median dropped from 2.3 to 0.7 $\mu g/m^3$. Where smoking was banned, it dropped to 0.2 $\mu g/m^3$ (Hammond et al. 1995). Thus, smoking policies also effectively reduced secondhand smoke concentrations in these nonoffice settings (Figure 4.5).

Exposure in Public Places

Exposures to secondhand smoke in public places have been particular public health concerns for more than two decades. Although these sites are workplaces for some, they may now be the only source of secondhand smoke exposure for most of the U.S. population with no home or work exposures. Studies using biomarkers confirm that secondhand smoke exposure in public places continues to affect nonsmokers. Using NHANES III data, several investigators have shown that persons with no home or workplace exposures still had detectable levels of cotinine in their serum (Pirkle et al. 1996; Mannino et al. 2001). This finding suggests that many people are exposed to secondhand smoke in other locations.

Restaurants, Cafeterias, and Bars

Restaurants, cafeterias, and bars are worksites as well as public places where smoking is frequently unrestricted or restricted in a manner that does not effectively decrease exposure. Servers and bartenders working in environments where smoking is permitted may be exposed to high levels of secondhand smoke (Jarvis et al. 1992; Jenkins and Counts 1999). In a survey of 1,224 residents from Olmsted County, Minnesota, 57 percent of the respondents reported exposures to secondhand smoke: 44 percent reported exposures in restaurants, 21 percent reported exposures at work, and 19 percent reported exposures in bars (Kottke et al. 2001). A quarter of the respondents in the NHAPS study reported exposures in restaurants or bars on the previous day for an average of two and one-half hours (Klepeis 1999; Klepeis et al. 2001). Restaurants may be the principal point of secondhand smoke exposure for children from nonsmoking homes, and an exposure of even a short duration may be relevant to acute effects, such as inducing or exacerbating an asthma attack (Chapter 6, Respiratory Effects in Children from Exposure to Secondhand Smoke).

In eating establishments, a wide variability in factors determines the concentration of secondhand smoke, including the size of the room, ventilation rate, number of smokers, and smoking rate. Furthermore, these concentrations vary throughout the day and evening. Concentrations measured for one to two hours during lunch or dinner are likely to be much higher than the average concentrations measured during a full day or week. The nicotine concentrations measured in restaurants have ranged from less than detectable to values of 70 $\mu g/m^3$ (Table 4.6).

Tobacco smoke has long been considered a nuisance that interferes with the enjoyment of food. One approach to reducing exposures of nonsmokers has been to establish smoking and nonsmoking sections in restaurants. Nonsmoking sections generally do have lower concentrations of secondhand smoke (Lambert et al. 1993; Hammond 1999), but they neither eliminate secondhand smoke nor reduce secondhand smoke concentrations to insignificant levels. The concentrations of nicotine in nonsmoking sections of restaurants persist at high levels. For example, a study of seven restaurants in Albuquerque, New Mexico, found that half of them had concentrations above 1 $\mu g/m^3$ in the nonsmoking sections (Lambert et al. 1993). Similar results were noted in more than half of 71 restaurants surveyed in Indiana where nicotine concentrations were above 2 $\mu g/m^3$ in the nonsmoking sections (Hammond and Perrino 2002). In a study of waiters exposed to secondhand smoke, the average nicotine concentration was as high as 5.8 $\mu g/m^3$, with the upper end of the range at 68 $\mu g/m^3$ (Maskarinec et al. 2000).

Hammond (1999) reported that nicotine concentrations in cafeterias were somewhat higher than in restaurants; average values were between 6 and 14 $\mu g/m^3$. Out of the 37 samples from company cafeterias in Massachusetts that allowed or restricted workplace smoking, two-thirds had nicotine concentrations that were above 5 $\mu g/m^3$. Secondhand smoke concentrations measured during lunchtime at a medical center cafeteria revealed large gradients between the smoking and nonsmoking sections. The concentrations were generally 25 to 40 $\mu g/m^3$ in the smoking section, 2 to 5 $\mu g/m^3$ in a nonsmoking section that was

Table 4.4 Occupational exposures to nicotine among nonsmoking office workers stratified by the smoking policy in effect at the time of the measurements

Study	Worksite description	Year sampled	Number of samples
	Smoking permitted		
Schenker et al. 1986, 1990, 1992	Railroad clerks (personal)	1983–1984	31
Carson and Erikson 1988	Multiple worksites	Before 1988	28
Crouse and Carson 1989	Multiple worksites	Before 1989	32
Eatough et al. 1989	Multiple worksites	NR	28
Miesner et al. 1989	Two office buildings	1987–1988	3
Coultas et al. 1990	Social worker office (personal)	1986–1987	1
	Attorney office (personal)	1986–1987	1
	Stockbroker (personal)	1986–1987	1
	Multiple worksites (personal)	1986–1987	5
	Travel agent (personal)	1986–1987	2
Oldaker et al. 1990	Multiple worksites	Before 1990	156
Turner and Binnie 1990	Multiple worksites	Before 1990	33
	Multiple worksites (naturally ventilated)	Before 1990	17
Vaughan and Hammond 1990	Telephone company	1987	13
Guerin et al. 1992	Multiple worksites	Before 1990	194
Hammond et al. 1995; Hammond 1999	Labels and paper products	1991–1992	7
	Tool manufacturing	1991–1992	7
	Die manufacturer	1991–1992	4
	Textile finishing B	1991–1992	2
	Sintering metal	1991–1992	7
	Specialty chemicals	1991–1992	7
	Textile finishing A	1991–1992	3
	Newspaper B	1991–1992	19
	Union headquarters‡	1991–1992	15
Jenkins et al. 1996a	Multiple sites (personal)	1993–1994	<136
Sterling et al. 1996	Building 2 (personal)	1994	12
	Building 1 (personal)	1994	13
	Smoking restricted		
Miesner et al. 1989	Two office buildings	1987–1988	2
Vaughan and Hammond 1990	Telephone company	1988	19
Hammond et al. 1995; Hammond 1999	Filtration products	1991–1992	6
	Fiber optics	1991–1992	4
	Work clothing	1991–1992	4
	Film and imaging	1991–1992	7
	Valve manufacturer	1991–1992	8
	Newspaper A	1991–1992	7

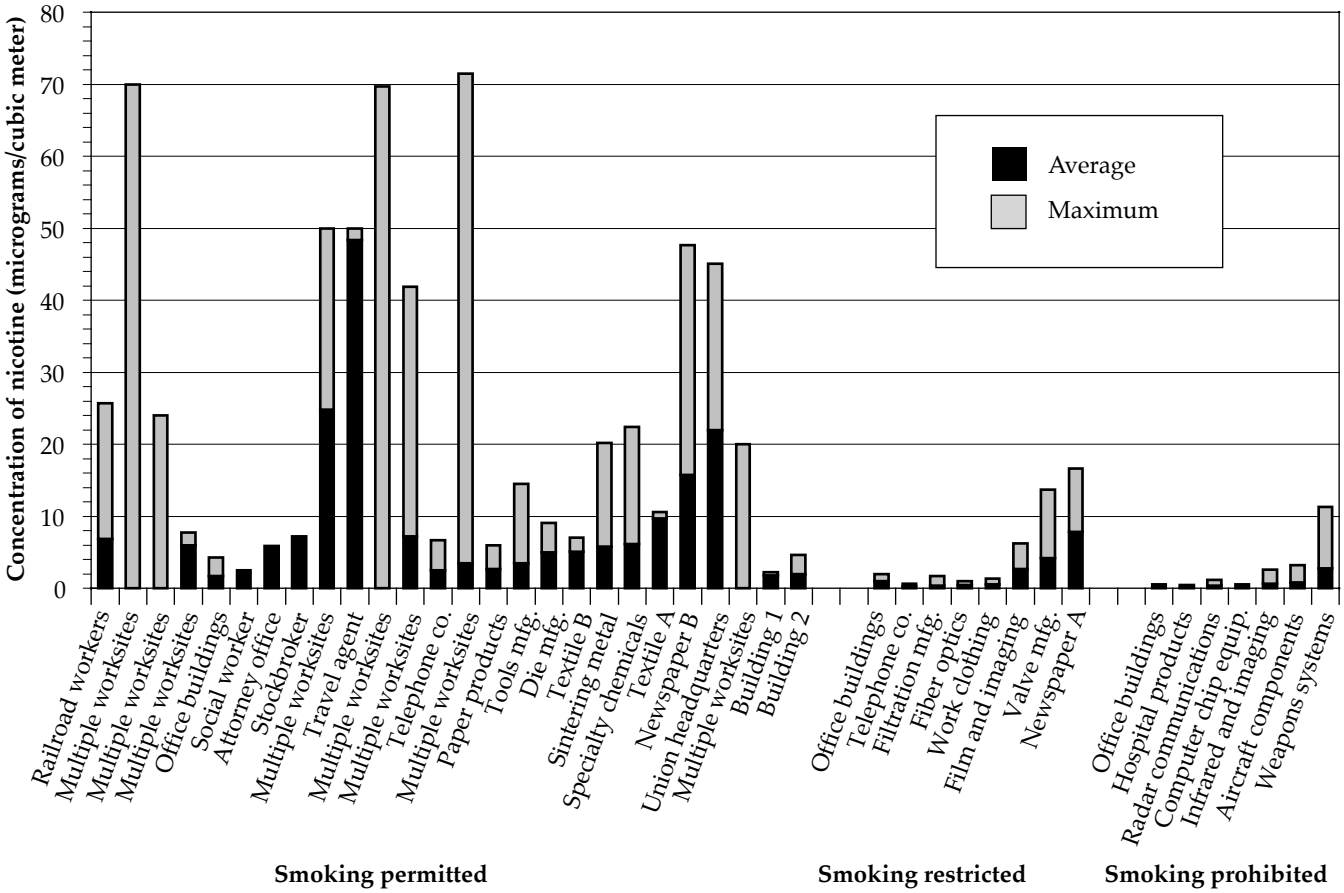
Concentrations of nicotine (micrograms per cubic meter [$\mu g/m^3$])					
Mean	**Standard deviation**	**Geometric mean**	**Minimum**	**Median**	**Maximum**
Smoking permitted					
6.9	6.7	3.2	<0.1	5.7	25.7
NR*	NR	7.2	LD†	NR	70.0
NR	NR	3.8	1.2	NR	24.0
6.0	NR	NR	4.1	NR	7.8
1.7	2.3	0.8	LD	0.6	4.3
2.5	NR	2.5	NR	2.5	NR
5.9	NR	5.9	NR	5.9	NR
7.2	NR	7.2	NR	7.2	NR
24.8	22.8	16.8	2.5	10.0	50.0
48.4	2.3	48.3	1.0	48.4	50.0
NR	NR	4.8	LD	NR	69.7
7.2	NR	NR	NR	LD	41.9
10.0	NR	NR	NR	LD	41.9
2.5	1.7	2.1	0.9	1.9	6.7
3.5	8.3	1.7	<1.6	NR	71.5
2.7	1.9	1.4	<0.05	2.6	6.0
3.5	4.9	3.5	0.8	1.4	14.5
5.0	4.2	3.2	0.7	5.1	9.1
5.1	2.8	4.7	3.1	5.1	7.1
5.8	8.9	1.6	0.3	0.9	20.2
6.2	7.8	2.0	<0.05	3.7	22.4
9.7	0.9	9.6	8.8	9.6	10.6
15.8	14.5	8.0	0.2	10.8	47.7
22.0	12.4	17.2	1.1	17.0	45.1§
NR	NR	NR	NR	1.9	>20.0§
1.8	NR	NR	1.1	1.7	2.3
2.0	NR	NR	0.3	1.6	4.7
Smoking restricted					
1.0	NR	NR	LD	1.0	2.0
0.3	0.2	0.2	<0.1	0.2	0.7
0.4	0.7	0.1	<0.05	0.1	1.7
0.5	0.4	0.4	0.2	0.4	1.0
0.6	0.5	0.5	0.3	0.4	1.4
2.7	2.2	2.0	0.6	1.8	6.3
4.2	4.5	2.5	0.5	2.5	13.7
7.9	5.9	5.2	0.6	7.6	16.7

Table 4.4 Continued

Study	Worksite description	Year sampled	Number of samples
	Smoking prohibited		
Miesner et al. 1989	Office building	1987–1988	2
Hammond et al. 1995; Hammond 1999	Hospital products	1991–1992	9
	Radar communications	1991–1992	4
	Computer chip equipment	1991–1992	1
	Infrared and imaging systems	1991–1992	8
	Aircraft components	1991–1992	5
	Weapons systems	1991–1992	3

*NR = Data were not reported.
†LD = Less than detectable.
‡Omits one data point, 130 $\mu g/m^3$.
§95th percentile, as given in paper.
Source: Hammond 1999.

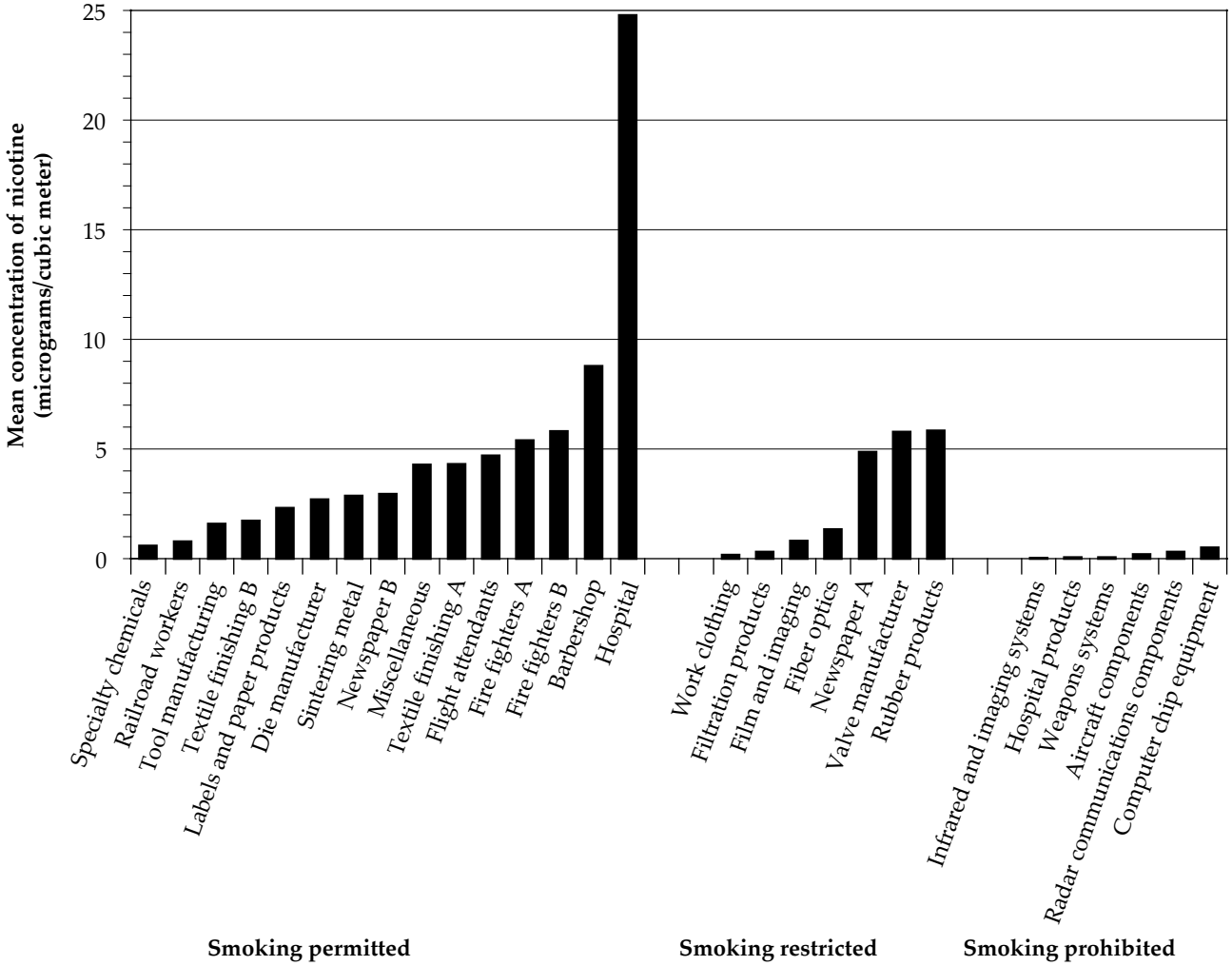
Figure 4.4 Occupational exposures to nicotine among groups of nonsmoking office workers



Note: Data are provided in detail in Table 4.4.

Concentrations of nicotine (micrograms per cubic meter [$\mu g/m^3$])					
Mean	**Standard deviation**	**Geometric mean**	**Minimum**	**Median**	**Maximum**
Smoking prohibited					
0.2	NR	NR	LD	0.2	0.4
0.1	0.2	0.1	<0.05	<0.05	0.4
0.4	0.3	0.2	<0.05	0.3	0.8
0.6	NR	NR	NR	0.6	NR
0.7	0.8	0.3	<0.05	0.4	1.9
0.8	1.0	0.4	<0.05	0.4	2.4
2.8	4.9	0.2	<0.05	<0.05	8.5

Figure 4.5 Mean concentrations of nicotine in nonoffice workplace settings with different smoking policies



Note: Data are provided in detail in Table 4.5.

Table 4.5 Occupational exposures to nicotine in nonoffice workplace settings among nonsmokers only, stratified by the smoking policy in effect at the time of the measurements

Study	Type of company	Year sampled	Number of samples
	Smoking permitted		
Schenker et al. 1986, 1990, 1992	Railroad workers (personal)	1983–1984	152
Mattson et al. 1989	Flight attendants (personal)	1988	16
Coultas et al. 1990	Barbershop (personal)	1986–1987	2
	Hospital (personal)	1986–1987	5
Guerin et al. 1992	Miscellaneous	Before 1990	282
Hammond et al. 1995; Hammond 1999	Specialty chemicals	1991–1992	8
	Tool manufacturing	1991–1992	13
	Textile finishing B	1991–1992	11
	Labels and paper products	1991–1992	1
	Die manufacturer	1991–1992	12
	Sintering metal	1991–1992	12
	Newspaper B	1991–1992	5
	Textile finishing A	1991–1992	11
	Firefighters A†	1991–1992	16
	Firefighters B	1991–1992	24
	Smoking restricted		
Hammond et al. 1995; Hammond 1999	Work clothing	1991–1992	9
	Filtration products	1991–1992	10
	Film and imaging	1991–1992	6
	Fiber optics	1991–1992	13
	Newspaper A	1991–1992	4
	Valve manufacturer	1991–1992	10
	Rubber products	1991–1992	2
	Smoking prohibited		
Hammond et al. 1995; Hammond 1999	Infrared and imaging systems	1991–1992	1
	Hospital products	1991–1992	5
	Weapons systems	1991–1992	12
	Aircraft components	1991–1992	12
	Radar communications components	1991–1992	13
	Computer chip equipment	1991–1992	10

Note: Concentrations were calculated by assuming that all smoking occurred during the workweek, although samplers were in place for 1 full week. Therefore, the nicotine was assumed to have been collected over 45 hours. The exceptions were the fire stations, where 112 hours were assumed.
*NR = Data were not reported.
†Omits one data point, 101 $\mu g/m^3$.
Source: Hammond 1999.

Concentrations of nicotine (micrograms per cubic meter [$\mu g/m^3$])					
Mean	**Standard deviation**	**Geometric mean**	**Minimum**	**Median**	**Maximum**
Smoking permitted					
0.8	3.3	0.2	<0.1	0.1	38.1
4.7	4.0	2.3	0.1	4.2	10.5
8.8	NR*	NR	4.0	NR	13.7
24.8	22.8	16.8	6.3	10.0	53.2
4.3	11.8	1.7	<1.6	<1.6	126.0
0.6	0.9	0.2	<0.05	0.5	2.8
1.6	1.0	1.2	0.2	1.8	3.4
1.7	1.7	1.1	0.3	0.9	5.1
2.3	NR	NR	NR	2.3	NR
2.7	1.3	2.5	1.2	2.4	5.4
2.9	2.6	2.1	0.6	2.2	9.7
3.0	1.4	2.7	1.2	2.8	4.6
4.3	8.8	1.8	0.5	1.4	30.7
5.4	3.8	4.1	1.2	4.8	13.4
5.8	6.8	3.8	0.7	3.6	27.5
Smoking restricted					
0.2	0.3	0.06	<0.05	<0.05	0.9
0.3	0.9	0.08	<0.05	<0.05	2.8
0.8	0.8	0.4	<0.05	0.7	2.2
1.3	2.8	0.6	0.2	0.6	10.6
4.9	6.6	2.6	0.9	1.8	14.8
5.8	7.8	3.6	1.2	3.3	27.3
5.8	5.4	4.2	2.1	5.8	9.6
Smoking prohibited					
<0.05	NR	NR	NR	<0.05	NR
0.08	0.17	<0.05	<0.05	<0.05	0.39
0.08	0.20	<0.05	<0.05	<0.05	0.63
0.20	0.18	0.13	<0.05	0.21	0.61
0.31	0.36	0.14	<0.05	0.26	1.08
0.51	0.33	0.41	0.15	0.39	1.08

Table 4.6 Concentrations of nicotine in restaurants

Study	Year sampled	State	Number of restaurants	Number of days	Number of samples
All sections					
Coghlin et al. 1989	1987	Massachusetts	6	NR*	NR
Crouse and Carson 1989	NR	NR	36	NR	NR
Miesner et al. 1989	1987–1988	NR	2	NR	NR
Thompson et al. 1989	NR	NR	34	NR	NR
Coultas et al. 1990	1986–1987	NR	1	NR	NR
Crouse and Oldaker 1990	NR	NR	21	NR	NR
	NR	NR	21	NR	NR
Oldaker et al. 1990	NR	NR	170	NR	NR
Jenkins et al. 1991	1991	NR	7	NR	NR
Lambert et al. 1993	1989	New Mexico	7	NR	NR
McFarling 1994	1994	Massachusetts	1	NR	NR
Maskarinec et al. 2000	1996–1997	Tennessee	NR	NR	32
	1996–1997 Waiters	Tennessee	NR	NR	83
Nonsmoking sections					
Lambert et al. 1993	1989	New Mexico	7	NR	NR
Moschandreas and Vuilleumier 1999	Before 1998	Illinois	1 theme restaurant	8	NR
	Before 1998	Illinois	1 gourmet restaurant	8	NR
Hammond and Perrino 2002	1998–1999	Indiana	71	NR	NR

*NR = Data were not reported.
†LD = Less than detectable.

Concentrations of nicotine (micrograms per cubic meter [$\mu g/m^3$])					
Mean	**Standard deviation**	**Geometric mean**	**Minimum**	**Median**	**Maximum**
			All sections		
NR	NR	NR	18.0	NR	70.0
NR	NR	4.1	1.0	NR	36.0
4.1	NR	NR	2.0	4.1	6.2
5.4	6.4	3.5	0.5	4.1	37.2
NR	NR	NR	NR	45.0	NR
4.3	NR	NR	LD†	2.9	24.0
6.3	NR	NR	0.3	4.2	24.8
NR	NR	5.1	LD	NR	23.8
3.4	NR	NR	LD	NR	16.1
NR	NR	NR	1.5	3.2	3.8
13.8	NR	NR	NR	NR	NR
6.0	11.9	NR	<0.24	0.8	49.3
5.8	11.9	NR	<0.24	1.2	67.9
			Nonsmoking sections		
NR	NR	NR	0.2	1.0	2.8
0.5	NR	NR	0.1	NR	1.2
1.1	NR	NR	0.1	NR	1.6
3.7	5.1	NR	0.02	2.2	26.7

within 25 feet of the smoking section, and less than 0.5 $\mu g/m^3$ in a nonsmoking section that was 30 feet from the smoking section (although on one day, the average in that section was 1.8 $\mu g/m^3$).

Among the highest concentrations of nicotine measured in public places were those found in bars and lounges, where reported values were generally greater than 50 $\mu g/m^3$ and occasionally were above 100 $\mu g/m^3$ (Table 4.7). Bartenders had higher exposures than waiters, at an average concentration of 14 $\mu g/m^3$ and a maximum exposure of more than 100 $\mu g/m^3$ (Maskarinec et al. 2000).

Other Locations

Casinos and bingo halls are other public locations where both nonsmoking workers and the public are exposed to high concentrations of secondhand smoke (Table 4.7). A 1986 study in California found a median nicotine concentration of 65.5 $\mu g/m^3$ (Kado et al. 1991). A study in Massachusetts the following year reported a median concentration of 56 $\mu g/m^3$ (Coghlin et al. 1989). In 1995, a study of casino workers in Atlantic City, New Jersey, showed increased levels of serum cotinine at baseline (geometric mean cotinine 1.34 ng/mL) that rose following a workshift (geometric mean cotinine 1.85 ng/mL) (Trout et al. 1998); nicotine levels in the personal breathing zone of casino workers ranged from 6 to 12 $\mu g/m^3$.

Reported nicotine concentrations in bowling alleys were between 10 and 23 $\mu g/m^3$ (Coghlin et al. 1989; Jenkins et al. 1996a) (Table 4.7). And although indoor exposures are expected to be higher than outdoor exposures, McFarling (1994) reported one nicotine sample at an outdoor baseball game that was at a concentration of 2.4 $\mu g/m^3$. Researchers have previously reported data for commercial aircraft, an environment now entirely smoke-free in the United States (Holm and Davis 2004).

Special Populations

Prisoners

Some of the highest concentrations of secondhand smoke in living quarters have been measured in correctional facilities (Hammond and Emmons 2005). Although most living and sleeping areas averaged 3 to 10 $\mu g/m^3$, Hammond and Emmons (2005) reported nicotine concentrations that averaged 25 $\mu g/m^3$ in a gym that was used as a bunkroom.

Evidence Synthesis

Since 1986, investigators have reported a substantial amount of new evidence on exposure to secondhand smoke. The more recent data provide insights into typical patterns of exposure, exposure in key microenvironments, and the consequences of various policies intended to reduce exposure. As noted in Figure 4.1 and Table 4.1, exposures of nonsmokers to secondhand smoke have declined significantly between 1988 and 2002. These declines have been observed in both children and nonsmoking adults, in both men and women, and in all racial and ethnic categories. However, significant levels of exposure persist for the U.S. population in general and for susceptible populations. Table 4.2 notes estimates for 2000; approximately 127 million children and nonsmoking adults were exposed to secondhand smoke. This estimated total includes almost 22 million children aged 3 through 11 years, and 18 million nonsmoking youth aged 12 through 19 years.

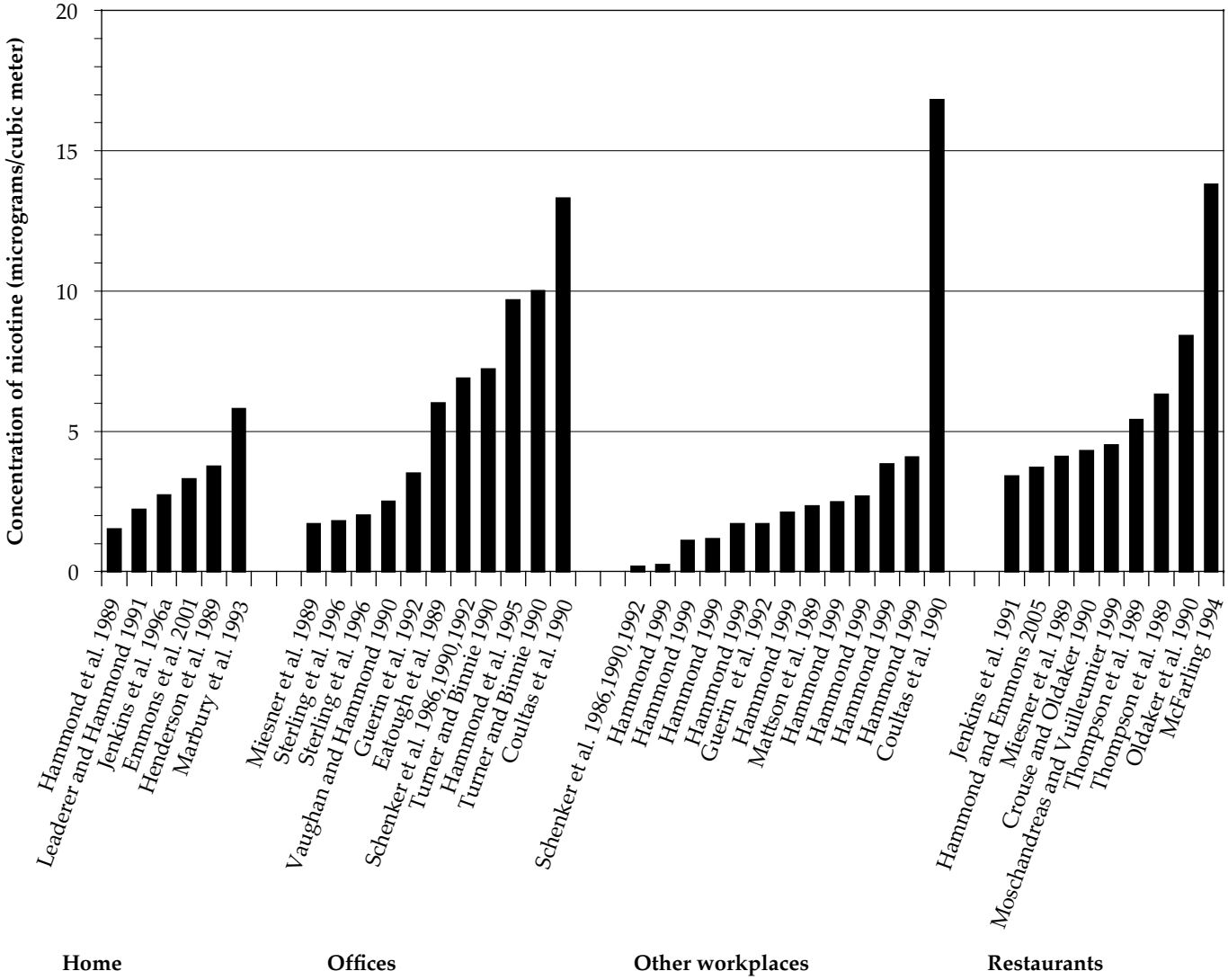
The findings consistently show the importance of two microenvironments as places for secondhand smoke exposure: the home and the workplace. Although microenvironments such as bars and restaurants may also be important for patrons, the home and the workplace are particularly significant because of the amount of time spent in these two locations. For the workplace, restrictions and smoking bans lead to much lower concentrations of secondhand smoke than in locations where smoking is allowed.

National surveys indicate that progress in reducing secondhand smoke exposure has been variable across the country. Certain states, such as California, Maryland, and Utah, have made significant advances in protecting nonsmokers, but others, such as Kentucky and Nevada, have not (Gilpin et al. 2001; Shopland et al. 2001). Even in locales with smoking restrictions in place, significant pockets of exposure remain, most notably in homes, some worksites such as restaurants and bars, and in automobiles. Exposures in some of these locations can be remedied by changing public policy. Exposures in other locations, particularly homes and automobiles, can perhaps only be addressed through education that alters lifestyle behaviors.

It is likely that geographic differences in secondhand smoke exposure are related to trends in tobacco use and policies that determine where tobacco use is permitted (Giovino et al. 1995; Gilpin et al. 2001). Wide regional differences exist within the United States

in secondhand smoke exposure and cotinine levels. In the NHANES III data, children with and without reported exposures had lower cotinine levels if they lived in the western part of the United States (Mannino et al. 2001)—a finding that may reflect lower community exposures to secondhand smoke. Where smoking is allowed, especially at worksites and in public places, concentrations are highly variable, so concentrations in individual locations may be significantly higher than average. Concentrations of secondhand smoke are also typically higher in the workplace and in restaurants than in the home (Figure 4.6). Policies that restrict smoking to particular areas reduce but do not eliminate secondhand smoke exposure. Smoke-free polices reduce secondhand smoke concentrations far more effectively.

Figure 4.6 Average concentrations of nicotine in homes, offices, other workplaces, and restaurants where smoking is permitted



Note: Data are provided in detail in Tables 4.3, 4.4, 4.5, and 4.6.

Table 4.7 Concentrations of nicotine in bars, lounges, and other public venues

Study	Year sampled	State	Number of venues	Number of days	Number of samples
		Bars			
Coghlin et al. 1989	1987	Massachusetts	11	NR*	NR
Loefroth et al. 1989	NR	North Carolina	1	2	NR
Miesner et al. 1989	1987–1988	NR	3	NR	5
Oldaker and Conrad 1989	NR	NR	NR	NR	NR
Jenkins et al. 1991	NR	NR	8	NR	NR
Guerin et al. 1992	NR	NR	2	NR	NR
Bergman et al. 1996	NR	NR	3	NR	17
Maskarinec et al. 2000	1996–1997	Tennessee	NR	NR	53
	1996–1997 Bartenders	NR	NR	NR	80
		Bingo halls			
Coghlin et al. 1989	1987	Massachusetts	NR	NR	2
Kado et al. 1991	1986	California	NR	NR	6
McFarling 1994	1994	NR	NR	NR	1
		Casinos and other betting establishments			
Jenkins et al. 1991	NR	NR	NR	NR	2
Kado et al. 1991	NR	NR	NR	NR	NR
Trout et al. 1998	1996	New Jersey	1	NR	1
		Bowling alleys			
Coghlin et al. 1989	1987	Massachusetts	NR	NR	2
Jenkins et al. 1991	NR	NR	NR	NR	4
		Professional baseball games			
McFarling 1994	1994	Massachusetts	NR	NR	1

*NR = Data were not reported.

Concentrations of nicotine (micrograms per cubic meter [$\mu g/m^3$])					
Mean	**Standard deviation**	**Geometric mean**	**Minimum**	**Median**	**Maximum**
Bars					
NR	NR	NR	6.0	NR	82.0
65.5	NR	NR	60.0	NR	71.0
7.4	4.4	6.0	1.1	7.0	13.0
59.2	NR	NR	6.1	NR	109.0
17.6	NR	NR	1.8	NR	91.0
12.9	NR	NR	4.1	NR	21.6
37.1	6.9	36.0	28.0	34.9	50.0
14.4	16.9	NR	<0.2	5.8	61.1
14.1	20.9	NR	<0.2	4.4	116.0
Bingo halls					
NR	NR	NR	53.0	56.0	60.0
NR	NR	NR	4.4	65.5	85.4
NR	NR	NR	NR	7.8	NR
Casinos and other betting establishments					
10.7	NR	NR	NR	NR	NR
NR	NR	NR	NR	65.5	NR
10.0	NR	8.0	6.0	NR	12.0
Bowling alleys					
18.0	NR	NR	13.0	18.0	23.0
10.7	NR	NR	NR	NR	NR
Professional baseball games					
2.4	NR	NR	NR	NR	NR

Conclusions

1. The evidence is sufficient to infer that large numbers of nonsmokers are still exposed to secondhand smoke.

2. Exposure of nonsmokers to secondhand smoke has declined in the United States since the 1986 Surgeon General's report, *The Health Consequences of Involuntary Smoking*.

3. The evidence indicates that the extent of secondhand smoke exposure varies across the country.

4. Homes and workplaces are the predominant locations for exposure to secondhand smoke.

5. Exposure to secondhand smoke tends to be greater for persons with lower incomes.

6. Exposure to secondhand smoke continues in restaurants, bars, casinos, gaming halls, and vehicles.

Overall Implications

Exposure to secondhand smoke remains a serious public health problem in the United States, with exposure of almost 60 percent of children aged 3 through 11 years and more than 40 percent of nonsmoking adults. Since the publication of the 1986 Surgeon General's report, measured levels of exposure in the United States have declined significantly. However, the proportional decrease has been larger among adults than among children, and the most recent data suggest that children aged 3 through 11 years have serum cotinine concentrations that are more than twice as high as those among nonsmoking adults. Data suggest that the home remains the most important target for reducing exposures to secondhand smoke, particularly for children but also for middle-aged and older adults. Although progress has been made to protect nonsmoking workers, continuing efforts are needed to protect these workers, and particularly younger workers, in all occupational categories.

Research questions remain regarding exposure to secondhand smoke. As noted in the 1986 report, no indicator has been developed that can objectively estimate long-term exposure or early-life exposure. Secondhand smoke exposure from "shared air spaces" within a building is also of concern, as a significant proportion of the population lives in apartment buildings or condominiums where smoking in another part of the building might increase tobacco smoke exposure for households of nonsmokers.

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