Publication No. 91-108
June 1991

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION
NIOSH

Current Intelligence Bulletin 54: Environmental Tobacco Smoke in the Workplace - Lung Cancer and Other Health Effects[1]

The National Institute of Occupational Safety and Health[2]

Current Intelligence Bulletins (CIBs) are issued by the National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control, Atlanta, Georgia, to disseminate new scientific information about occupational hazards. A CIB may draw attention to a formerly unrecognized hazard, report new data on a known hazard, or disseminate information on hazard control.

CIBs are distributed to representatives of academia, industry, organized labor, public health agencies, and public interest groups, as well as to Federal agencies responsible for ensuring the safety and health of workers.

Copies are available to individuals upon request from the Division of Standards Development and Technology Transfer, NIOSH (Robert A. Taft Laboratories, 4676 Columbia Parkway, Cincinnati, Ohio 45226). We welcome suggestions concerning the content, style, and distribution of these documents.

The purpose of this bulletin is to disseminate information about the potential risk of cancer to workers exposed to environmental tobacco smoke (ETS). In 1964, the Surgeon General issued the first report on smoking and health, which concluded that cigarette smoking causes lung cancer. Since then, research on the toxicity and carcinogenicity of tobacco smoke has demonstrated that the health risk from inhaling tobacco smoke is not limited to the smoker, but also includes those who inhale ETS. ETS contains many of the toxic agents and carcinogens that are present in mainstream smoke, but in diluted form. Recent epidemiologic studies support and reinforce earlier published reviews by the Surgeon General and the National Research Council demonstrating that exposure to ETS can cause lung cancer. These reviews estimated the relative risk of lung cancer to be approximately 1.3 for a nonsmoker living with a smoker compared with a nonsmoker living with a nonsmoker. In addition, recent evidence also suggests a possible association between exposure to ETS and an increased risk of heart disease in nonsmokers. Although these data were not gathered in an occupational setting, ETS meets the criteria of the Occupational Safety and Health Administration (OSHA) for classification as a potential occupational carcinogen [Title 29 of the Code of Federal Regulations, Part 1990]. NIOSH therefore considers ETS to be a potential occupational carcinogen and recommends that exposures be reduced to the lowest feasible concentration. All available preventive measures should be used to minimize occupational exposure to ETS. NIOSH urges employers to disseminate this information to employees. NIOSH also requests that professional and trade associations and unions inform their members about the potential hazards of exposure to ETS. Readers seeking more detailed information about the studies cited in this bulletin are urged to consult the original publications.

J. Donald Millar, M.D., D.T.P.H. (Lond.)
Assistant Surgeon General
Director, National Institute for
Occupational Safety and Health
Centers for Disease Control

1. This document is NIOSH Publication No. 91-108. Publication date: June 1991.

2. National Institute for Occupational Safety and Health, 200 Independence Avenue, SW, Washington, DC, 20201. Phone: (800)356-4674.

ABSTRACT

The National Institute for Occupational Safety and Health (NIOSH) has determined that environmental tobacco smoke (ETS) is potentially carcinogenic to occupationally exposed workers. In 1964, the Surgeon General issued the first report on smoking and health, which concluded that cigarette smoke causes lung cancer. Since then, research on the toxicity and carcinogenicity of tobacco smoke has demonstrated that the health risk from inhaling tobacco smoke is not limited to the smoker, but also includes those who inhale ETS. ETS contains many of the toxic agents and carcinogens that are present in mainstream smoke, but in diluted form. Recent epidemiologic studies support and reinforce earlier published reviews by the Surgeon General and the National Research Council demonstrating that exposure to ETS can cause lung cancer. These reviews estimated the relative risk of lung cancer to be approximately 1.3 for a nonsmoker living with a smoker compared with a nonsmoker living with a nonsmoker. In addition, recent evidence suggests a possible association between exposure of nonsmokers to ETS and an increased risk of heart disease.

Although these data were not gathered in an occupational setting, ETS meets the criteria of the Occupational Safety and Health Administration (OSHA) for classifying substances as potential occupational carcinogens [Title 29 of the Code of Federal Regulations, Part 1990]. NIOSH therefore recommends that ETS be regarded as a potential occupational carcinogen in conformance with the OSHA carcinogen policy, and that exposures to ETS be reduced to the lowest feasible concentration. Employers should minimize occupational exposure to ETS by using all available preventive measures.

ACKNOWLEDGMENTS

This bulletin was prepared by the Division of Standards Development and Technology Transfer (DSDTT), Richard W. Niemeier, Ph.D., Director, and the Division of Surveillance, Hazard Evaluations, and Field Studies (DSHEFS), Lawrence J. Fine, M.D., Director. David M. Votaw, DSDTT, developed this document with the help of Kyle Steenland, Ph.D., DSHEFS, who developed the epidemiology section. The contributions of other National Institute for Occupational Safety and Health (NIOSH) personnel are gratefully acknowledged: David D. Bayse, Ph.D.; Philip J. Bierbaum; Robert M. Castellan, M.D.; Jerome P. Flesch; Hugh J. Hansen, Ph.D.; Bryan D. Hardin, Ph.D.; G. Kent Hatfield, Ph.D.; Frank J. Hearl; Marvin D. Mills; William J. Moorman, Ph.D.; John E. Parker, M.D.; Edward L. Petsonk, M.D.; Laurence D. Reed; Leslie T. Stayner, Ph.D.; and Ralph D. Zumwalde.

Ruth E. Grubbs and Anne C. Hamilton performed editorial review and coordinated production; Vanessa L. Becks and Susan R. Kaelin provided editorial assistance and produced camera-ready copy; and Judith G. Curless typed the draft.

INTRODUCTION

The Surgeon General has concluded that tobacco smoke is a carcinogen and an important risk factor for heart disease. The purpose of this bulletin is to disseminate information about the potential carcinogenicity of environmental tobacco smoke[1] (ETS) in the workplace. Evidence is now clear that the health risk from inhaling tobacco smoke is not limited to the smoker, but also includes those who inhale ETS. Recent epidemiologic studies of nonsmokers exposed to ETS have shown an increased relative risk for lung cancer compared with unexposed nonsmokers. In addition, recent evidence suggests that exposure of nonsmokers to ETS may be associated with an increased risk of heart disease. This bulletin describes the results and implications of these studies.

The conclusions and recommendations in this Current Intelligence Bulletin (CIB) are based on the following:

- Reports of the Surgeon General on the health effects of tobacco smoke
- Comparison of the chemical composition of ETS with that of mainstream smoke[2] (MS).
- Results from recent epidemiologic studies of nonsmokers exposed to ETS

Methods for controlling involuntary exposures to ETS in the workplace are also discussed.

REPORTS OF THE SURGEON GENERAL ON THE HEALTH EFFECTS OF TOBACCO SMOKE

In 1964, the Surgeon General issued the first report on smoking and health, which concluded that cigarette smoke causes cancer [DHEW 1964]:

> Cigarette smoking is causally related to lung cancer in men; the magnitude of the effect of cigarette smoking far outweighs all other factors. The data for women, though less extensive, point in the same direction.... The risk of developing lung cancer increases with

duration of smoking and the number of cigarettes smoked per day, and is diminished by discontinuing smoking.

Since 1964, evidence has continued to support the causal relationship between exposure to cigarette smoke and lung cancer, demonstrating that risk increases with amount and duration of smoking. Subsequent research has increased our knowledge about the toxicity and carcinogenicity of tobacco smoke and the risks of exposure. Additional support for the Surgeon General's conclusion has come from (1) animal studies that demonstrated the carcinogenicity of tobacco smoke condensate, and (2) analytical studies demonstrating that tobacco smoke contains carcinogens [DHEW 1972; DHHS 1982]. Cigarette smoking is the major cause of lung cancer (87% of lung cancer deaths) and is estimated to account for 30% of all cancer deaths [DHHS 1989].

The 1964 Surgeon General's report also pointed out that male cigarette smokers have higher death rates from heart disease than nonsmokers. Subsequent reports have concluded that cigarette smoking is a major cause of heart disease and that smoking is a major independent risk factor for heart attack [DHEW 1968; DHHS 1983].

On July 1, 1965, Congress approved the Federal Cigarette Labeling and Advertising Act of 1965 (Public Use 89-92). This law, which became effective on January 1, 1966, was the first of a continuing series of Federal statutes enacting warning labels to inform the public about the health hazards of smoking and, subsequently, the use of other tobacco products. Presently, the Comprehensive Smoking Education Act (Public Law 98-474) [Title 15, SS 1331 of the U.S. Code] requires cigarette companies to rotate four health warnings on all cigarette packages and in advertisements.

COMPARISON OF THE CHEMICAL COMPOSITION OF ETS AND MS

ETS contains many of the toxic agents and carcinogens that are present in MS, but in diluted form [DHHS 1986]. The major source of ETS is sidestream smoke[3] (SS), which contains higher amounts of some toxic and carcinogenic agents than MS when it is obtained in its undiluted form under laboratory conditions [DHHS 1989]. For example, the release of volatile N-nitrosamines and aromatic amines is higher in SS than in MS.

A major reason that undiluted SS and MS have different concentrations of toxic and carcinogenic agents is that peak temperatures in the burning cone of a cigarette reach 800 to 900°C during puffing, but only 600°C between puffs, resulting in less complete combustion of tobacco during generation of SS. In addition, most of the burning cone is oxygen deficient during smoldering and produces a strongly reducing environment [NRC 1986]. Table 1 lists 26 toxic and carcinogenic agents identified in SS and MS.

ETS is diluted in the air before it is inhaled and thus is less concentrated than MS. However, active inhalation of MS is limited to the time it takes to smoke each cigarette, whereas exposure to ETS is constant over the period spent in the ETS-polluted environment. This fact is reflected in measurements of nicotine uptake by smokers and ETS-exposed nonsmokers [DHHS 1989].

POTENTIAL FOR OCCUPATIONAL EXPOSURE

Approximately 29% of the U.S. adult population smokes cigarettes, and exposure to ETS is common [DHHS 1989]. Many people who report no exposure to ETS have low concentrations of cotinine (a metabolite of nicotine) in their urine, indicating exposure. The average concentration of cotinine in the urine of nonsmokers has been reported to be approximately 8 ng/ml compared with approximately 1,200 ng/ml in smokers [Cummings et al. 1990]. The National Research Council (NRC) estimated that nonsmokers exposed to ETS averaged 25 ng of cotinine/ml, and active smokers averaged 1,825 ng/ml [NRC 1986]. Husgafvel-Pursiainen et al. [1987] found that nonsmoking restaurant workers had an average urinary cotinine concentration of 56 ng/ml, and nonsmokers not exposed to ETS had an average concentration of 8.3 ng/ml. Other investigators have shown that nonsmokers living with smokers have approximately two to three times the amount of urinary cotinine as nonsmokers living with nonsmokers [Haley et al. 1989].

Exposures to ETS were measured by respirable suspended particulates (<2.5 pm) and averaged 242 pg/m^3 in public access buildings [First 1984; NRC 1986; Repace and Lowrey 1980, 1982]. Studies reviewed by Repace and Lowrey [1990] suggested a 62% probability of exposure to ETS for a nonsmoker in the workplace. However, the relative contribution of work versus home environments in ETS exposure has not been well quantified. In addition, social settings outside the workplace or the home (e.g., restaurants and bowling alleys) may contribute significantly to ETS exposure.

Table 1. Toxic and carcinogenic agents in undiluted cigarette SS*,**

Compound	Type of toxicity	Amount in SS (per cigarette)	Ratio of SS/MS
Vapor phase:			
Carbon monoxide	T	26.8-61 mg	2.5-14.9
Carbonyl sulfide	T	2-3mg	0.03-0.13
Benzene	c	400-500µg	8-10
Formaldehyde	c	1,500µg	50
3-Vinylpyridine	SC	300-450µg	24-34
Hydrogen cyanide	T	14-110µg	0.06-0.4
Hydrazine	c	90ng	3
Nitrogen oxides	T	500-2,000µg	3.7-12.8
N-nitrosodimethylamine	C	200-1,040ng	20-130
N-nitrosopyrrolidine	C	30-390ng	6-120
Particulate phase:			
Tar	C	14-30mg	1.1-15.7
Nicotine	T	2.1-46mg	1.3-21
Phenol	TP	70-250µg	1.3-3.0
Catechol	CoC	58-290µg	0.67-12.8
o-Toluidine	C	3µg	18.7
2-Naphthylamine	C	70ng	39
4-Aminobiphenyl	C	140ng	31
Benz(a)anthracene	C	40-200ng	2-4
Benzo(a)pyrene	C	40-70ng	2.5-20
Quinoline	C	15-20µg	8-11
N'-nitrosonornicotine	C	0.15-1.7µg	0.5-5.0
NNK	C	0.2-1.4µg	1.0-22
N-nitrosodiethanolamine	C	43ng	1.2
Cadmium	C	0.72µg	7.2
Nickel	C	0.2-2.55µg	13-30
Polonium-210	C	0.5-1.6pCi	1.06-3.7

* Sources: DHHS [1989]; Hoffmann and Hecht [1989].
** Abbreviations: C, carcinogenic; CoC, cocarcinogenic; MS, mainstream smoke; SC, suspected carcinogen; SS, sidestream smoke; T, toxic; T?, tumor promoter; NNK, 4-(methyl-nitrosamino)-(3-pyridyl)- 1 -butanone.

On the basis of urinary cotinine concentrations, the NRC [1986] concluded that nonsmokers exposed to ETS absorb the equivalent of 0.1 to 1.0 cigarette per day. On the basis of 1985 data, NIOSH estimates that each cigarette smoker in the United States smokes an average of about 21 cigarettes per day [NCHS 1988]. Blood and urine samples analyzed for vapor phase nicotine indicate that nonsmokers exposed to ETS absorb about 1% of the tobacco combustion products absorbed by active smokers [NRC 1986; DHHS 1986].

EPIDEMIOLOGIC STUDIES OF NONSMOKERS EXPOSED TO ETS

Lung Cancer

Surgeon General

The Surgeon General first addressed the possible health effects of involuntary smoking in 1972 [DHEW 1972]. Evidence associating adverse health effects with ETS exposure continued to be reported, and in 1986, the Surgeon General's report entitled The Health Consequences of Involuntary Smoking focused entirely on this subject [DHHS 1986]. This report cited 3 cohort

studies and 10 case-control studies that together documented an approximately 1.3-fold increase in the risk of lung cancer among nonsmoking women, usually wives exposed to their husbands' ETS. The 1986 Surgeon General's report concluded that involuntary smoking is a cause of disease (including lung cancer) in healthy nonsmokers; however, more data on the dose and distribution of ETS exposure in the population are needed to accurately estimate the magnitude of risk in the U.S. population [DHHS 1986].

NRC [1986]

The NRC also reviewed the important epidemiologic data available in 1986 (3 cohort studies and 10 case-control studies) on the adverse health effects of ETS exposure. These studies were the same ones reviewed by the Surgeon General, except for one case-control study. The statistical power of a single study is often small, but it can be improved by analyzing all the data simultaneously across all studies (meta-analysis). Using this approach, the NRC estimated that the relative risk for nonsmokers married to smokers was 1.25 compared with nonsmokers married to nonsmokers, taking into account the possible misclassification of smokers as nonsmokers. Using data from urinary cotinine tests to estimate the extent of ETS exposure, the NRC also estimated that the relative risk of lung cancer for nonsmokers exposed to ETS at home, at work, or elsewhere was 1.42 compared with unexposed nonsmokers, with a plausible range of 1.24 to 1.61. The NRC concluded that "the weight of the evidence derived from epidemiologic studies shows an association between ETS exposure of nonsmokers and lung cancer that, taken as a whole, is unlikely to be due to chance or systematic bias."

Wald et al. [1986]

In another quantitative meta-analysis covering the same studies reviewed by the NRC, Wald et al. [1986] reached similar conclusions. Their analysis showed a 30% greater risk of lung cancer (relative risk 1.30) for nonsmokers living with smokers relative to nonsmokers living with nonsmokers. The authors concluded that this result was unlikely to have occurred by chance and that it underestimated the true risk associated with exposure to ETS because nonsmokers living with nonsmokers are exposed to ETS in other settings (e.g., at work). The relative risk is thus based on a reference group that is partially exposed.

Blot and Fraumeni [1986]

Blot and Fraumeni [1986] analyzed the same studies reviewed by the Surgeon General and the NRC except for one case-control study. Combining data across the reviewed studies, these investigators concluded that the overall relative risk for nonsmoking women married to husbands who smoked was 1.3 (95% confidence interval [CI], 1.1- 1.5) compared with nonsmoking women married to nonsmokers. These authors also concluded that the relative risk for nonsmokers exposed to heavy smoking was 1.7 (95% CI, 1.4-2.1). They found that the epidemiologic studies strongly suggested an increased risk that was biologically plausible, but that limitations in assessing ETS exposure had introduced uncertainty.

Eight additional studies of lung cancer and ETS exposure among those who never smoked have been published since the reviews by the Surgeon General [DHHS 1986; NRC 1986; Wald et al. 1986; Blot and Fraumeni 1986] (Table 2).

Hole et al. [1989]

Hole et al. [1989] updated an earlier cohort study [Gillis et al. 1984] of 3,960 men and 4,037 women in Scotland. These men and women had lived in the same households and had been followed for an average of 11.5 years. They were aged 45-64 at the time of the original interviews, which took place from 1972 to 1976. The unexposed group was defined as persons who never smoked and lived with nonsmokers at the time of interview. The exposed group was composed of persons who never smoked and lived with smokers. A third group was composed of persons who had smoked during some period in the past. In the followup study [Hole et al. 1989], only 2 deaths from lung cancer occurred in the unexposed group and 7 in the exposed group, compared with 147 deaths from lung cancer among smokers. The adjusted relative risk for the exposed group was 2.41 (95% CI, 0.45-12.83), compared with a relative risk of 10.64 for persons who had smoked in the past. The risk for smokers was the same whether or not they were exposed to ETS.

Brownson et al. [1987]

Brownson et al. [1987] conducted a case-control study of persons diagnosed with adenocarcinoma of the lung. A subset of 19 nonsmoking women was identified from this group and was compared with 47 controls. Exposure to ETS was classified as less than 4 hr/day or more than 4 hr/day (there was no specification of when this exposure occurred). The odds ratio for those exposed more than 4 hr/day was 1.68 (95% CI,

Table 2. Recent studies of lung cancer among ETS-exposed persons who never smoked

Study	Design	Exposure definition	Relative risk*	Comment
Update of Gillis et al. [1984] by Hole et al.	12-yr followup, 3,960 men and 4,037 women aged 45-64 in 1972-76	Living with smoker or ex-smoker at the time of the survey	2.41 (CI, 0.45-12.83; 7 observed	Adjusted for age, sex, and social class
Brownson et al. [1987]	19 cases, 47 controls	Exposure for >4 hr\day	1.68 (CI, 0.39-2.97)	Adjusted for age, income and occupation
Humble et al. [1987]	28 cases, 54 controls	Lived with spouse who smoked	For cigarette ETS exposure: 2.2 (90% CI, 1.0-4.9) For any type of ETS exposure: 2.6 (90% CI, 1.2-5.6	Adjusted for ethnicity and age
Gao et al. [1987]	246 cases, 375 controls	Lived with a smoker	<20 yr, 1.0; 20-29 yr, 1.1 (CI, 0.7-1.8); 30-39 yr, 1.3 (CI, 0.8-2.1); >40yr, 1.7 (CI, 1.0-2.9)	Adjusted for age and education
Lam et al. [1987]	199 cases, 375 controls	Lived with a smoker	1.65 (CI, 1.16-2.35)	Matched for age and neighborhood
Janerich et al. [1990]	191 cases, 335 controls	Lived with a spouse who smoked	1.65 (CI, 1.16-2.35)	Matched for age, sex, and county of residence; relative risk for spousal smoking = 0.9
Shimizu et al. [1988]	90 cases, 191 controls	>25 smoker-yr of exposure during childhood	2.07 (CI, 1.16-3.68)	Matched for age, sex, and hospital; relative risk for spousal smoking = 1.1
Geng et al. [1988]	54 cases, 93 controls	Lived with spouse who smoked	2.16 (CI, 1.03-4.53)	Matched for race, age, and marital status; positive dose response; methodologic details not presented

* Confidence interval is 95% unless otherwise indicated.

0.39-2.97) after adjustment for confounders, whereas the odds ratio for those exposed fewer than 4 hr/day was 1.00. The study does not state whether the nonsmoking females had ever smoked, but the implication is that they had never smoked. Because many of the subjects were deceased, smoking status was often determined from interviews with next of kin. The study lacked sufficient sample size to draw substantive conclusions, but it did suggest an increased risk for adenocarcinoma among nonsmokers exposed to ETS.

Humble et al. [1987]

Humble et al. [1987] evaluated the risk of lung cancer in a case-control study of 28 lung cancer patients who never smoked and lived with a smoking spouse compared with a control group of 54 persons who never smoked and lived with a nonsmoking spouse. Surrogate responses about smoking habits were used for 19 of the 28 cases, with most of these data provided by the spouse.

The adjusted odds ratio for nonsmokers living with a spouse who smoked cigarettes was 2.2 (90% CI, 1.0-4.9), and it was 2.6 (90% CI, 1.2-5.6) for nonsmokers exposed to any type of ETS (including pipes and cigars). There was no trend of increasing risk with increased duration of exposure or increased amount regularly smoked by the spouse. In addition, marriage to a smoker did not increase the risk for persons who had ever smoked. This study contained no data on exposure to ETS outside the home or from other persons (nonspouses) living in the home.

Gao et al. [1987]

Gao et al. [1987] studied 672 female lung cancer patients and 735 population-based controls in Shanghai, China. Patients had been diagnosed as having lung cancer between 1984 and 1986, and both patients and controls were all interviewed directly. The odds ratio (adjusted for age and education) was 0.9 (95% CI, 0.6-1.4) for persons who had ever lived with a smoker during adulthood, and 1. 1 (95% CI, 0.7-1.7) for those who had ever lived with a smoker during childhood. However, for 246 married patients and 375 married controls, risk increased with increasing years of marriage to a spouse who smoked, reaching 1.7 (95% CI, 1.0-2.9) among nonsmokers who lived with a smoker for more than 40 years.

Lam et al. [1987]

Lam et al. [1987] studied 445 female lung cancer patients in Hong Kong matched by age with 445 female controls from the same neighborhood. Analyses (unmatched) for exposure to ETS included 199 married patients and 335 married controls who never smoked. A small number of persons who were not married and never smoked (5% to 6% of the patients and controls) were also included and treated as unexposed to ETS. Wives exposed to ETS from a husband who smoked had an odds ratio of 1.65 (95% CI, 1.16-2.35), with the predominant type of cancer being adenocarcinoma (odds ratio 2.12). These odds ratios were not adjusted for any confounders.

Janerich et al. [1990]

Janerich et al. [1990] conducted a population-based case-control study of 191 persons who never smoked and were diagnosed with lung cancer from 1982 to 1984; this group was compared with individually matched controls who never smoked. Controls were matched by age, sex, and county of residence. Surrogate interviews were necessary for 62 cases and thus were also conducted for their matched controls. The number of years of exposure to ETS in the home was calculated by summing the number of smokers in the home per year across all years of life. The number of years exposed to ETS outside the home was also estimated, although details were not given in the report. Childhood and adolescent exposures in the home, adult exposures in the home, and adult exposures outside the home all contributed about equally to total lifetime exposure to ETS. For spouses, ETS exposure was also calculated by multiplying the number of packs smoked per day by the number of years the spouse smoked. The major finding of the study was a trend of increasing lung cancer risk with increasing years of exposure during childhood. Household exposure to ETS for 25 or more years that included childhood doubled the risk of lung cancer (odds ratio, 2.07; 95 % CI, 1.16-3.68). No consistent increase in cancer risk occurred with increasing years of adulthood exposure to all sources of ETS, but persons exposed for the greatest number of years showed the highest risk (odds ratio, 1.11; 95% CI, 0.56-2.20). Separate analyses of exposure to ETS from spousal smoking found no excess risk of lung cancer for individuals married to smokers, and no trend of increased risk with increased years of exposure or with increased amount smoked by the spouse. Odds ratios in this study were not adjusted for any confounders, and odds ratios for exposure to ETS from spousal smoking do not appear to have been adjusted for childhood ETS exposures.

Shimizu et al. [1988]

Shimizu et al. [1988] published a case-control study of 90 female lung cancer patients who never smoked. Each patient was matched by age, hospital, and admission date to 2 controls of the same sex who did not have lung cancer (for 17 patients, only 1 control was used). Information was gathered about occupation, exposure to ETS, diet, and cooking fuels. The risk of lung cancer was significantly elevated for women who never smoked and lived in a home where the mother smoked (relative risk, 4.0; $P<0.05$) or the paternal grandfather smoked (relative risk, 3.2; $P<0.05$). Exposure to the ETS of other household members (including the husband, the father, and the children) was not associated with increased risk. The relative risk for exposure to ETS at work was 1.2. The authors found no increasing trend in risk with the number of cigarettes smoked by the mother or the paternal grandfather. However, the authors indicated that the subjects had trouble recalling the amount of smoking to which they had been exposed. The authors also pointed out that in Japan, children spend considerable time with their mother in the home, and less with the father; it is also common for the retired father of the husband to live in his son's home.

Geng et al. [1988]

Geng et al. [1988] studied 54 nonsmoking (undefined) women with lung cancer in Tianjin, China. These patients were matched with controls by race, age, sex, and marital status. The authors reported a significantly elevated odds ratio for the patients exposed to ETS from spouses (odds ratio, 2.16; 95% CI, 1.03-4.53), but it is not clear whether these women included former smokers. Their risk increased with the amount and duration (years) of the husband's smoking.

Table 3. Recent studies of hear disease among ETS-exposed persons who never smoked

Study	Design	Exposure definition	Relative risk	Comment
Update of Gillis et al. [1984] by Hole et al. [1989]**	12-yr followup, 3,960 men and 4,037 women aged 45-64 in 1972-76	Living with a smoker or ex-smoker in early 1970's	2.01 (CI, 1.21-3.35; 485 observed)	Adjusted for cardiovascular risk factors***, positive dose response
Humble et al. [1990]	20-yr followup, 513 women aged 40+	Living with smoker in 1960	1.59 (CI, 0.99-2.57)	Adjusted for cardiovascular risk factors, dose response in some strata
Helsing et al. [1988]	12-yr followup, 4,162 men and 14,873 women, aged 25+ in 1963	Living with smoker or ex-smoker in 1963	Men: 1.31 (CI, 0.99-2.57)	Adjusted for cardiovascular risk factors, dose response among women only
Svendsen et al. [1985, 1987]****	7-yr average followup, 1,245 men aged 35-57 in 1973-82	Married to smoker or ex-smoker	1.61 (CI, 0.96-2.71; 90 observed)	Adjusted for cardiovascular risk factors, positive dose response
Garland et al. [1985]	10-yr followup, 695 women aged 50-79 in 1972-74	Married to a smoker or ex-smoker	2.9 (estimate; 19 observed)	Adjusted for age
Hiryama [1984]	16-yr followup, 91,540 women aged 40+	Married to a smoker or ex-smoker	Low exposure: 1/10 (90% CI, 0.91-1.33)	Significant dose response

* Confidence interval is 95% unless otherwise indicated.
** Hole et al. [1989] provide updated results of the same population studied by Gillis et al. [1984].
*** Serum cholesterol, blood pressure, and body mass index.
**** Svendsen et al. [1987] is the full report of the abstract published by Svendsen et al. [1985].

Summary of Results from Lung Cancer Studies

The studies published since 1986 have concentrated on ETS exposure through spousal smoking during adulthood [Hole et al. 1989; Brownson et al. 1987; Humble et al. 1987; Gao et al. 1987; Lam et al. 1987; Janerich et al. 1990; Shimizu et al. 1988; Geng et al. 1988], although some studies include data on childhood exposures [Janerich et al. 1990; Shimizu et al. 1988; Gao et al. 1987]. The data from these more recent studies do not individually demonstrate a clear causal relationship between ETS exposure and lung cancer, but their consistent finding of a relative risk greater than 1.0 for nonsmokers exposed to ETS provides evidence of a positive association. These data are consistent with and reinforce the reviews by NRC [1986], DHHS [1986], Blot and Fraumeni [1986], and Wald et al. [1986], all of which concluded that ETS exposure is associated with an increased risk of lung cancer for nonsmokers.

The most important limitation observed in all studies reporting lung cancer risks among persons who never smoked is the lack of quantitative ETS exposure data. Most studies have defined exposure to ETS for nonsmokers on the basis of living with or being married to a smoker. All of the case-control studies ascertained the potential for exposure by interviewing subjects and controls (or surrogates) without any other independent assessment of ETS exposure. Questionnaires often failed to include specific questions about afl sources of ETS. Most studies included limited or no information about the risk of lung cancer from ETS exposure in the workplace.

The potential exists for a positive bias, particularly in the case-control studies, where ex-smokers with lung cancer might have been misclassified as never having smoked. The misclassified ex-smokers are more likely to be married to smokers and to develop lung cancer than those who never smoked. However, the NRC [1986] estimated that the effect of such misclassification would have been relatively slight and could not entirely account for the increased risk of lung cancer following exposure to ETS. This conclusion by the NRC is based on calculations that assume a degree of misclassification

(based on nonsmoker urinary cotinine data) and its likely effect on the observed lung cancer risk. In addition, the risk of lung cancer in these studies is based on a reference group of nonsmokers living with nonsmokers who are exposed to ETS in other settings. This background exposure results in underestimation of the true risk.

Several risk assessments have been performed for persons who never smoked and were exposed to ETS. The NRC [1986] estimated that of the 7,000 lung cancer deaths reported in 1985 among U.S. women who never smoked, 2,010 (29%) were attributable to ETS. The corresponding number for men was 820 (16%) of the 5,200 lung cancer deaths among U.S. males who never smoked. Wells [1988] estimated that approximately 3,000 of the lung cancer deaths reported in 1985 among persons who never smoked occurred as a result of ETS exposure. Repace and Lowrey [1990] estimated that approximately 5,000 of the lung cancer deaths reported in 1988 among persons who never smoked and ex-smokers occurred as a result of ETS exposure. These risk assessments used a 1.3 to 1.5 relative risk of lung cancer for nonsmokers exposed to ETS at home or elsewhere compared with unexposed persons. The number of deaths attributable to ETS exposure was derived using standard formulas for attributable risks [Kleinbaum et al. 1983] with the estimated number of annual lung cancer deaths in the United States for persons who have never smoked.

Heart Disease

Surgeon General

The Surgeon General [DHHS 1986] reviewed four epidemiologic studies of cardiovascular disease in persons exposed to ETS [Lee et al. 1986; Hirayama 1984; Gillis et al. 1984; Garland et al. 1985] (Table 3). He concluded that further studies on the relationship between involuntary smoking and cardiovascular disease are needed in order to determine whether involuntary smoking increases the risk of cardiovascular disease. More detailed characterizations of exposure to ETS and specific types of cardiovascular disease associated with this exposure are needed before an effect of involuntary smoking on the etiology of cardiovascular disease can be established.

NRC [1986]

The NRC [1986] reviewed four epidemiologic studies that evaluated the association between heart disease and ETS exposure [Garland et al. 1985; Gillis et al. 1984; Hirayama 1984; Svendsen et al. 1985, 1987[4]] (Table 3). The same NRC review examined studies of the effects of ETS exposure on heart rate and blood pressure among healthy individuals. No statistically significant increases were found in heart disease or effects on heart rate and blood pressure. The NRC report concluded that with respect to chronic cardiovascular morbidity and mortality, although biologically plausible, there is no evidence of statistically significant effects due to ETS exposure, apart from the study by Hirayama (see Table 3) in Japan."

Other Epidemiologic and Experimental Studies

Since publication of the reports by the NRC and the Surgeon General, researchers have published two epidemiologic studies of heart disease and ETS exposure [Humble et al. 1990; Helsing et al. 1988], and one update [Hole et al. 1989] of an earlier cohort study [Gillis et al. 1984] (Table 3). Experimental studies of the effects of ETS on the heart have also been published [Davis et al. 1989; Allred et al. 1989; Sheps et al. 1990].

The studies reported by Hole et al. [1989], Helsing et al. [1988], and Humble et al. [1990] associated ETS exposure with an increase of heart disease among persons who never smoked. The studies by Hole et al. [1989] and Helsing et al. [1988] are both large follow-up cohort studies that used direct interviews of men and women who lived in the same household. Study of these cohorts demonstrated an excess of heart disease in persons who lived with smokers and never smoked compared with persons who lived with nonsmokers and never smoked. Furthermore, Hole et al. [1989] and Humble et al. [1990] show an increasing risk for heart disease mortality with increasing exposure to ETS at home. Helsing et al. [1988] found a similar trend in women but not men.

Experimental studies support the hypothesis that ETS exposure has deleterious effects on platelets and the endothelium [Davis et al. 1989] and can decrease the time to onset of angina pectoris in patients with coronary artery disease [Allred et al. 1989]. Allred et al. [1989] reported that the time to angina decreased in heart disease patients who exercised after exposure to airborne carbon monoxide (CO) at concentrations producing 2% and 3.9% carboxyhemoglobin (COHb) in the blood. Sheps et al. [1990] observed that arrhythmias in heart disease patients increased when they exercised after exposure to airborne CO at concentrations producing 6% COHB in the blood. Persons exposed to ETS in unventilated areas have been shown to have COHB concentrations of 2% to 3% [NRC 1986].

Wells [1988] estimated that among nonsmokers in the United States, 32,000 deaths from heart disease each year were attributable to ETS exposure. Wells used estimated rates for death from heart disease among nonsmokers and a relative risk of 1.30 for ETS-exposed nonsmokers compared with unexposed nonsmokers.

Glantz and Parmley [1991] recently reviewed the epidemiologic literature on exposure to ETS and heart disease (including the studies in Table 3) from 1984 to the present. These researchers estimated a 30% increase (relative risk, 1.30; 95% CI, 1.2-1.4) in the risk of death from ischemic heart disease or myocardial infarction in nonsmoking individuals exposed to ETS at home. Glantz and Parmley also noted that several of these studies found a dose-response relation between the amount of smoking by the spouse and the risk of heart disease in the nonsmoking spouse; they concluded that exposure to ETS can cause heart disease.

Summary of Results from Heart Disease Studies

The principal limitation found in the lung cancer studies also applies to the studies of heart disease in persons exposed to ETS-that is, the indirect method of assessing exposure to ETS (usually defined as spousal smoking). The second limitation of these heart disease studies is the difficulty in controlling for all known cardiovascular risk factors (e.g., blood pressure, serum cholesterol, and body mass index). In addition, the risk of heart disease for ETS-exposed persons who never smoked seems large compared with the risk of heart disease for smokers. Unlike lung cancer mortality, where the relative risk for smokers compared with nonsmokers is 22.4 for men and 11.9 for women, the relative risk of heart disease mortality for smokers compared with nonsmokers is 1.9 for men and 1.8 for women [DHHS 1989]. Note that the nonsmoking comparison group for these risk estimates includes those exposed to ETS.

Other Adverse Health Effects

Several additional adverse health effects have been associated with ETS exposure, including cervical cancer [Slattery et al. 1989], ischemic stroke [Donnan et al. 1989], spontaneous abortion [Ahlborg 1990], and low birthweight [NRC 1986]. However, evidence is insufficient to draw conclusions about the relationship of ETS exposure to these health effects.

CONCLUSIONS

In 1964 the Surgeon General concluded that cigarette smoke Causes lung cancer. Since that time, additional research on the toxicity and carcinogenicity of tobacco smoke has demonstrated that the health risks from inhaling tobacco smoke are not limited to smokers, but also include those who inhale ETS. ETS contains many of the toxic agents and carcinogens found in MS, but in diluted form. Recent epidemiologic studies support and reinforce the conclusions of the reviews by the Surgeon General and the NRC demonstrating that exposure to ETS can cause lung cancer. These reviews estimated the relative risk for lung cancer to be approximately 1.3 for nonsmokers living with smokers compared with nonsmokers living with nonsmokers. In addition, recent evidence also suggests a possible association between exposure to ETS and an increased risk for heart disease in nonsmokers. The recent epidemiologic studies (including those associating ETS with other adverse health effects) point to a pattern of health effects that is similar for both smokers and nonsmokers exposed to ETS.

NIOSH recognizes that these recent epidemiologic studies have several shortcomings: lack of objective measures for characterizing and quantifying exposures, failure to adjust for all confounding variables, potential misclassification of ex-smokers as nonsmokers, unavailability of comparison groups that have not been exposed to ETS, and low statistical power. Nonetheless, NIOSH has determined that the collective weight of evidence (i.e., that from the Surgeon General's reports, the similarities in composition of MS and ETS, and the recent epidemiologic studies) is sufficient to conclude that ETS poses an increased risk of lung cancer and possibly heart disease to occupationally exposed workers. The epidemiologic data are not sufficient to draw conclusions about other health effects such as cervical cancer, ischemic stroke, spontaneous abortion, and low birthweight.

RECOMMENDATIONS

Several systems exist for classifying a substance as a carcinogen. Such classification systems have been developed by NTP [1989], IARC [1987], and OSHA [29 CFR 1990]. NIOSH considers the OSHA classification system (Identification, Classification, and Regulation of Potential Occupational Carcinogens [29 CFR 1990], also known as the OSHA carcinogen policy) the most appropriate for use in identifying occupational carcinogens[5]. The Surgeon General has concluded that cigarette smoke causes lung cancer as well as heart disease. Table 1 lists 21 known or suspected

carcinogens, cocarcinogens, and tumor promoters identified as components of ETS and MS in analytical studies. Furthermore, a large body of evidence indicates that exposure to ETS has produced lung cancer in nonsmokers. NIOSH therefore considers ETS to be a potential occupational carcinogen in conformance with the OSHA carcinogen policy [29 CFR 1990].

The risk of developing cancer should be decreased by minimizing exposure to ETS. Employers should therefore assess conditions that may result in worker exposure to ETS and take steps to reduce exposures to the lowest feasible concentration.

METHODS FOR CONTROLLING INVOLUNTARY EXPOSURE TO ETS

Workers should not be involuntarily exposed to tobacco smoke. To prevent worker exposures to any hazardous substance, employers should first eliminate hazardous workplace emissions at their source. If elimination is not possible, emissions should be removed from the pathway between the source and the worker [NIOSH 1983]. Therefore, the best method for controlling worker exposure to ETS is to eliminate tobacco use from the workplace and to implement a smoking cessation program. Until tobacco use can be completely eliminated, employers should protect nonsmokers from ETS by isolating smokers. Methods for eliminating tobacco use from the workplace and isolating smokers are described here briefly.

Eliminating Tobacco Use from the Workplace

Worker exposure to ETS is most efficiently and completely controlled by simply eliminating tobacco use from the workplace. To facilitate elimination of tobacco use, employers should implement smoking cessation programs. The Association of Schools of Public Health (ASPH) has recommended the following strategy for smoking cessation [NIOSH 1986]. Specifically, management and labor should work together to develop appropriate nonsmoking policies that include some or all of the following:

- Prohibit smoking at the workplace and provide sufficient disincentives for those who do not comply
- Distribute information about health promotion and the harmful effects of smoking
- Offer smoking-cessation classes to all workers
- Establish incentives to encourage workers to stop smoking

Further information regarding workplace smoking policies and smoking cessation programs can be found in No Smoking: A Decision Maker's Guide to Reducing Smoking at the Worksite [American Cancer Society et al. 1985].

Isolating Smokers

The 1986 Surgeon General's report on involuntary smoking concluded that, the simple separation of smokers and nonsmokers within the same airspace may reduce, but does not eliminate, the exposure of nonsmokers to ETS." In indoor workplaces where smoking is permitted, ETS can spread throughout the airspace of all workers. The most direct and effective method of eliminating ETS from the workplace is to prohibit smoking in the workplace. Until that is achieved, employers can designate separate, enclosed areas for smoking, with separate ventilation. Air from this area should be exhausted directly outside and not recirculated within the building or mixed with the general dilution ventilation for the building. Ventilation of the smoking area should meet general ventilation standards, and the smoking area should have slight negative pressure to ensure airflow into the area rather than back into the airspace of the workplace [ASHRAE 1989]. Guidance for designing local exhaust ventilation systems can be found in Recommended Industrial Ventilation Guidelines [Hagopian and Bastress 1976], Industrial Ventilation-A Manual of Recommended Practice [ACGIH 1986], and Fundamentals Governing the Design and Operation of Local Exhaust Systems [ANSI 1979].

Warning signs should be posted at the entrances to the workplace in both English and the predominant language of non-English-reading workers. These signs should state that smoking is prohibited or permitted only in designated smoking areas. If designated smoking areas are provided, they should be clearly identified by signs.

RESEARCH NEEDS

Research is needed to investigate the following issues:

- More accurate quantification of the increased risk of lung cancer associated with ETS exposure, including determination of other contributing factors (e.g., occupational exposures) that may accentuate the risk.

- Determination of the concentration and distribution of ETS components in the workplace to help quantify the risk for the U.S. working population.

- The association of ETS exposure with cancer other than lung cancer.

- The relationship between ETS exposure and cardiovascular disease.

- The relationship between ETS exposure and nonmalignant respiratory diseases such as asthma, bronchitis, and emphysema, and the effects of ETS on lung function and respiratory symptoms.

- Possible mechanisms of ETS damage to the cardiovascular system, such as increased platelet aggregation, increased CORB leading to oxygen deprivation, or damage to the endothelium.

- Effects of workplace smoking restrictions on the ETS exposure of nonsmokers and ETS related health effects in nonsmokers.

APPENDIX POSITIONS OF OTHER AGENCIES REGARDING ETS

The Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA) have not established permissible exposure limits (PEU) for ETS in the workplace. OSHA is now preparing to address this issue as part of an indoor air quality standard.

The U.S. Environmental Protection Agency (EPA) states that ETS is a known cause of lung cancer and respiratory symptoms and that it has been linked to heart disease. EPA also recommends that exposure to ETS be minimized wherever possible by restricting smoking to separately ventilated areas directly exhausted to the outside, or by entirely eliminating smoking in buildings [EPA 1989].

The International Agency for Research on Cancer [IARC 1986] stated that epidemiologic studies have demonstrated an increased risk of lung cancer for nonsmoking spouses of smokers. Although researchers had substantial difficulty in determining exposure to ETS and other risk factors for the cancers studied, IARC concluded that passive smoking gives rise to some risk of cancer. IARC also concluded that there is sufficient evidence that tobacco smoke is carcinogenic to humans," and that there is sufficient evidence that inhalation of tobacco smoke as well as topical application of tobacco smoke condensate cause cancer in experimental animals."

Table 4. Commonly used abbreviations in this Current Intelligence Bulletin

Abbrev-iations	Meanings
ASPH	Association of Schools of Public Health
c	carcinogenic
CO	carbon monoxide
COHb	carboxyhemoglobin
CoC	cocarcinogenic
CI	confidence interval
CIB	Current Intelligence Bulletin
°C	degree Celsius
DSDTT	Division of Standards Development and Technology Transfer
DSHEFS	Division of Surveillance, Hazard Evaluations, and Field Studies EPA U.S. Environmental Protection Agency
EPA	U.S. Environmental Protection Agency
ETS	environmental tobacco smoke (tobacco smoke in the ambient atmosphere composed of sidestream smoke and exhaled mainstream smoke)
IARC	International Agency for Research on Cancer
m	meter
MS	mainstream smoke (smoke drawn through the tobacco and into the smoker's mouth)
mg	milligram
ml	milliliter
mm	millimeter
MSHA	Mine Safety and Health Administration
ng	nanogram
NIOSH	National Institute for Occupational Safety and Health
NNK	4-(methyl-nitrosamino)-(3-pyridyl)- 1-butanone
NRC	National Research Council
OSHA	Occupational Safety and Health Administration
P	probability
pCi	picocurie
PEL	permissible exposure limit
SC	suspected carcinogen
sec	second
SS	sidestream smoke (smoke generated by smoldering tobacco between puffs and smoke diffusing through the cigarette paper and escaping from the burning cone during puffing)
T	toxic
TP	tumor promoter
µg	microgram
µm	micrometer

ABBREVIATIONS

Table 4 lists commonly used abbreviations in this Current Intelligence Bulletin.

REFERENCES

ACGIH [1986]. Industrial ventilation: a manual of recommended practice. 19th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

Ahlborg G Jr. [1990]. Epidemiologic studies on occupational factors and pregnancy outcome. Arbete och Halsa 14:1-65.

Allred EN, Bleecker ER, Chairman BR, Dahms TE, Gottlieb SO, Hackney JD, et al. [1989]. Shorttertn effects of carbon monoxide exposure on the exercise performance of subjects with coronary artery disease. N Engl J Med 321(21):1426-1432.

American Cancer Society, American Heart Association, American Lung Association [1985]. No smoldng: a decision maker's guide to reducing smoldng at the wotksite. Washington, DC: U.S. Department of Health and Human Services, Public Health Service, Office of Disease Prevention and Health Promotion, and Office on Smoking and Health.

ANSI [1979]. American national standardfundamentals governing the design and operation of local exhaust systems. New York, NY: American National Standards Institute, Inc., ANSI Z9.2-1979.

ASHRA.E [1989]. Ventilation for acceptable indoor air quality. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., ASHRAE 62-1989.

Blot WJ, Fraumeni JF Jr. [1986]. Passive smoking and lung cancer. JNCI 77(5): 993-1000.

Brownson RC, Reif JS, Keefe TJ, Ferguson SW, Pritzl JA [1987]. Risk factors for adenocarcinoma of the lung. Am J Epidemiol 125(l):25-34.

29 CFR 1990. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Cummings KM, Markello SJ, Mahoney M, Bhargava AK, McElroy PD, Marshall JR [1990]. Measurement of current exposure to environmental tobacco smoke. Arch Environ Health 45(2):74-79.

Davis JW, Shelton L, Watanabe IS, Arnold J [1989]. Passive smoking affects endothelium and platelets. Arch Intern Med 149:386-389.

DHEW [1964]. Smoking and health. Report of the advisory committee to the Surgeon General of the Public Health Service. Rockville, MD: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, PHS Publication No. 1103.

DHEW [1968]. The health consequences of smoking. A public health service review: 1967. U.S. Department of Health, Education, and Welfare, Public Health Service, PHS Publication No. 1696.

DHEW [1972]. The health consequences of smoking. A report of the Surgeon General: 1972. Rockville, MD: U.S. Department of Health, Education, and Welfare, Public Health Service, Health Services and Mental Health Administration, DHEW Publication No. (HSM) 72-7516.

DHHS [1982]. The health consequences of smoking: cancer. A report of the Surgeon General. U.S. Department of Health and Human Services, Public Health Service, Office on Smoking and Health, DHHS Publication No. (PHS) 82-50179.

DHHS [1983]. The health consequences of smoking: cardiovascular disease. A report of the Surgeon General. Rockville, MD: U.S. Department of Health and Human Services, Public Health Service, Office on Smoking and Health, DHHS Publication No. (PHS) 84-50204.

DHHS [1986]. The health consequences of involuntary smoking. A report of the Surgeon General. Rockville, MD: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, Center for Health Promotion and Education, Office on Smoking and Health, DHHS Publication No. (CDC) 87-8398.

DHHS [1989]. Reducing the health consequences of smoking: 25 years of progress. A report of the Surgeon General. Rockville, MD: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, DHHS Publication No. (CDC) 89-841 1.

Donnan GA, Adena NU, O'Malley HM, McNeil JJ, Doyle AE, Neill GC [1989]. Smoking as a risk

factor for cerebral ischaemia. Lancet, September 16, pp.643-647.

EPA [1989]. Indoor air facts: environmental tobacco smoke. No. 5. Washington, DC: U.S. Environmental Protection Agency, Office of Air and Radiation (ANR-445).

First MW [1984]. Environmental tobacco smoke measurement: retrospect and prospect. Eur J Respir Dis 5(Suppl):9-16.

Gao YT, Blot WJ, Zheng W, Ershow AG, Hsu CW, Levin L et al. [1987]. Lung cancer among Chinese women. Int J Cancer 40(5):604-609.

Garland C, Baffett-Connor E, Suarez L, Criqui NM, Wingard DL [1985]. Effects of passive smoldng on ischemic heart disease mortality of nonsmokers. Am J Epidemiol 121(5):645-650.

Geng G-Y, Liang ZH, Zhang AY, Wu GL [1988]. On the relationship between smoking and female lung cancer. In: Aold M, Hisamichi S, Tominaga S, eds. Smoking and health 1987: proceedings of the 6th World Conference on Smoldng and Health, Tokyo, 9-12 November 1987. Amsterdam, The Netherlands: Elsevier Science Publishers, pp. 483-486.

Gillis CR, Hole DJ, Hawthorne VM, Boyle P [1984]. The effect of environmental tobacco smoke in two urban communities in the west of Scotland. Eur J Respir Dis 65(Suppl 133):121126.

Glantz SA, Partnley WW [1991]. Passive smoking and heart disease: epidemiology, physiology, and biochemistry. Circulation 83(l):1-12.

Hagopian JH, Bastress EK [1976]. Recommended industrial ventilation guidelines. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 76-162.

Haley NJ, Colosimo SG, Axelrad CM, Harris R, Sepkovic DW [1989]. Biochemical validation of self-reported exposure to environmental tobacco smoke. Environ Res 49:127-135.

Helsing KJ, Sandler DP, Conistock GW, Chee E [1988]. Heart disease mortality in nonsmokers living with smokers. Am J Epidemiol 12 7(5):915 922.

Hirayama T [1984]. Lung cancer in Japan: effects of nutrition and passive smoldng. In: Nfizell M and Correa P, eds. Proceedings of the International Lung Cancer Update Conference. Tokyo, Japan: Verlag Chemie International, pp. 175-195.

Hoffmann D, Hecht SS [1989]. Advances in tobacco carcinogenesis. In: Grover P, ed. Handbook of experimental pharmacology 1988. New York, NY: Springer Verlag.

Hole DJ, Gillis CR, Chopra C, Hawthorne VM [1989]. Passive smoking and cardiorespiratory health in a general population in the west of Scotland. Br Med J No. 6696, 299:423-427.

Humble C, Croft J, Gerber A, Casper M, Hames CG, Tyroler HA [1990]. Passive smoking and 20-year cardiovascular disease mortality among nonsmoking wives, Evans County, Georgia. Am J Public Health 80(5):599-601.

Humble CG, Samet JM, Pathak DR [1987]. Marriage to a smoker and lung cancer risk. Am J Public Health 77(5):598-602.

Husgafvel-Pursiainen K, Sorsa M, Engstrm K, Einist P [1987]. Passive smoking at work: biochemical and biological measures of exposure to environmental tobacco smoke. Int Arch Occup Environ Health 59:337-345.

IARC [1986]. IARC monograph on the evaluation of the carcinogenic risk of chemicals to humans: tobacco smoldng. Vol. 38. Lyon, France: World Health Organization, International Agency for Research on Cancer.

IARC [1987]. IARC monographs on the evaluation of carcinogenic risks to humans: overall evaluations of carcinogenicity; an updating of IARC monographs. Vols. 1 through 42, Suppl. 7. Lyon, France: World Health Organization, International Agency for Research on Cancer, pp. 17-34.

Janerich DT, Thompson WD, Varela LR, Greenwald P, Chorest S, Tucci C, et al. [1990]. Lung cancer and exposure to tobacco smoke in the household. N Engl J Med 323(10):632-636.

Kleinbaum L, Kupper L, Morganstern H [1983]. Epidemiologic research. San Jose, CA: Lifetime Publications.

Lam TH, Kung ITM, Wong CM, Lam WK, Kleevens JWL, Saw D, et al. [1987]. Smoking, passive smoking, and histological types in lung cancer in Hong Kong Chinese women. Br J Cancer 56:673-678.

Lee PN, Chamberlain J, Alderson MR [1986]. Relationship of passive smoking to risk of lung cancer and other smoking-associated diseases. Br J Cancer 54:97-105.

NCHS [1988]. Vital and health statistics: health promotion and disease prevention, United States, 1985. Hyattsville, NM: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Center for Health Statistics, DHHS Publication No. (PHS) 88-1591.

NIOSH [1983]. NIOSH comments to the U.S. Department of Labor: comments of the National Institute for Occupational Safety and Health. Presented at the Advance Notice of Proposed Rulemaldng (ANPR) meeting to OSHA for Docket H-160: health standards; methods of compliance, June 1983. NIOSH policy statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health.

NIOSH [1986]. Proposed national strategy for the prevention of leading work-related diseases anl injuries: a proposed national strategy for the prevention of occupational lung diseases. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 89-128.

NRC [1986]. Environmental tobacco smoke. Measuring exposures and assessing health effects. National Research Council, Board on Environmental Studies and Toxicology, Committee on Passive Smoking. Washington, DC: National Academy Press.

NTP [1989]. Fifth annual report on carcinogens: summary 1989. Research Triangle Park, NC: U.S. Department of Health and Human Services, Public Health Service, National Institute of Enviromnental Health Sciences, National Toxicology Program, NTP 89-239.

Repace JL, Lowrey AH [1980]. Indoor air pollution, tobacco smoke, and public health. Science 208:464-472.

Repace JL, Lowrey AH [1982]. Tobacco smoke, ventilation, and indoor air quality. ASHRAE Trans. 88:894-914.

Repace JL, Lowrey AH [1990]. Risk assessment methodologies for passive smoking-induced lung cancer. Risk Analysis 10(l):27-37.

Sheps DS, Herbst MC, Hinderliter AL, Adams KF, Ekelund LG, O'Neil JJ, et al. [1990]. Production of arrhythmias by elevated carboxyhemoglobin in patients with coronary artery disease. Ann Intern Med 113:343-351.

Shimizu H, Morishita M, Nfizuno K, Masuda T, Ogura Y, Santo M, et al. [1988]. A case-control study of lung cancer in nonsmoking women. Tohoku J Exp Med 154:389-397.

Slattery ML, Rebison LM, Schuman KL, French TK, Abbott TM, Overall JC, Gardner JW [1989]. Cigarette smoking and exposure to passive smoke are risk factors for cervical cancer. JAMA 261:1593-1598.

Svendsen KH, Kuller LH, NeatonJ [1985]. Effect of passive smoldng in the multiple risk factor intervention trial. American Heart Association 58th Scientific Sessions.

Svendsen KH, Kuller LH, Martin MJ, Ockene JK [1987]. Effects of passive smoking in the multiple risk factor intervention trial. Am J Epidemiol 126:783-795.

Wald NJ, Nanchahal K, Thompson SG, Cuckle HS [1986]. Does breathing other people's tobacco smoke cause lung cancer? Br Med J 293:12171222.

Wells AJ [1988]. An estimate of adult mortality in the United States from passive smoking. Environ Int 14:249-265.

1. *Tobacco smoke in the ambient atmosphere composed of sidestream smoke and exhaled mainstream smoke. See page viii for a complete list of definitions and abbreviations.*

2. *Smoke drawn through the tobacco and into the smoker's mouth.*

3. *Smoke generated by (1) smoldering tobacco between puffs, and (2) smoke diffusing through the cigarette paper and escaping from the burning cone during puffing.*

4. *Svendsen et al. [1985] is the abstract of the full report published in 1987 [Svendsen et al. 1987].*

5. *"'Potential occupational carcinogen' means any substance, or combination or mixture of substances, which causes an increased incidence of benign and/or malignant neoplasms, or a substantial decrease in the latency period between exposure and onset of neoplasms in humans or in one or more experimental mammalian species as the result of any oral, respiratory or dermal exposure, or any other exposure which results in the induction of tumors at a site other than the site of administration. This definition also includes any substance which is metabolized into one or more potential occupational carcinogens by mammals" [29 CFR 1990.103].*