RESEARCH TRIANGLE INSTITUTE

October 1984

A Preliminary Assessment of the Benefits of Reducing Formaldehyde Exposures

Draft Report

POST OFFICE BOX 12194 RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

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Prepared for

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EPA Contract No. 68-01-6595
RTI Project No. 2505-16

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PREFACE

This draft report is a preliminary assessment of the benefits of reducing formaldehyde exposures. While its objectives were to review the existing information and to provide qualitative evidence of benefits in a relatively short period of time, its overall purpose was to provide preliminary information to help the U.S. Environmental Protection Agency (EPA) plan future research and policy.

We would like to acknowledge the support of both our initial project officer, Debbie Dobkowski, and our current project officer, Dr. Al McGartland, from the Benefits staff of the Office of Policy Analysis. In addition, Dr. Gwen Waldman of the University of North Carolina and Dr. Thomas Stan of the Chemical Industry Institute of Toxicology provided valuable assistance for the health effects summary. Dr. Raymond Palmquist of North Carolina State University critiqued our efforts on the property value and benefits estimation tasks. Dr. William H. Desvousges of Research Triangle Institute participated in discussions throughout the study. Any errors or omissions, however, are the responsibility solely of the authors.

CHAPTER 1

INTRODUCTION AND SUMMARY

This draft report to the U.S. Environmental Protection Agency (EPA) describes a preliminary assessment of the benefits of reducing human exposures to formaldehyde. This chapter provides background information, outlines the basic components of benefit-cost assessment, lists the primary study objectives, and offers a summary of the study and its methodology. It concludes with a short guide to the remainder of the report.

1.1 BACKGROUND

EPA is faced with the critical task of developing the appropriate regulatory response(s) to limit human exposures to formaldehyde. In particular, under the Toxic Substance Control Act, EPA has the responsibility and the authority to regulate toxic substances, such as formaldehyde, that may pose a substantial risk to health. In addition, when a regulatory action imposes costs in excess of $100 million a year, it also falls under the purview of Executive Order 12291, which requires a regulatory impact analysis (RIA). For a formaldehyde regulation, an RIA would evaluate both the benefits and the costs of reduced exposures and consider their distributional implications.

With this regulatory background, this report reviews the evidence on the extent of the risks posed by human exposure to formaldehyde and provides a preliminary appraisal of the benefits of reducing these risks. In addition, it also reviews a variety of regulatory responses that EPA might consider in developing its regulatory strategies for controlling human formaldehyde exposures and previews some of the specific issues that may arise in a formaldehyde RIA. For example, the nature of formaldehyde* itself can

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*Formaldehyde is a colorless, pungent gas that is generally sold in an aqueous solution. It has a wide range of commercial applications, including industrial chemicals, agricultural products, fumigants and drugs. Its resins also are widely used in building products, textiles, and insulating materials.

dictate the number and type of analyses necessary to complete a formal RIA. On the costs side of the ledger, for example, an RIA would have to assess very carefully the many uses of formaldehyde in commercial products--e.g., industrial chemicals, drugs, and textile products--to properly estimate the costs of complying with the regulation. For the benefits side, on the other hand, the RIA would have to assess these same applications to determine where, and for whom, the regulation would reduce exposures--a potentially complex process for substances, such as formaldehyde, that are found both in the home and in the workplace.

1.2 BENEFIT-COST ASSESSMENT

As shown in Figure 1-1, benefit-cost assessment is a method of identifying, quantifying, valuing, and comparing alternative allocations of society's scarce resources. It attempts to bring to public policy decisions the discipline imposed on private decisionmakers by market pressures.

For a formaldehyde regulation, the first box in Figure 1-1, the regulatory initiative, is designed to directly or indirectly affect the rate, timing, concentration, or location of formaldehyde residuals released to the environment. Although both natural and human activities may result in the presence of formaldehyde in the ambient (outdoor) and indoor environments, concentrations are likely to be especially significant indoors because formaldehyde is typically released indoors and because the enclosing structure retains the contaminant fumes.

Formaldehyde is released in two basic indoor environments--in the workplace, where workers may be exposed, and in the home, where consumers may be exposed. In the workplace setting, formaldehyde is released both in industrial processes where it is manufactured or used and in the off-gassing of formaldehyde-containing products. Formaldehyde is also released in photochemical reactions in the presence of hydrocarbons such as those emitted in the combustion of fossil fuels, and from cigarette smoking.

In the home, the primary source of elevated concentrations is offgassing from formaldehyde-containing products. Products accounting for most concentrations include chipboard, particle board, plywood, textiles, and urea formaldehyde foam insulation (UFFI). The amount of offgassing

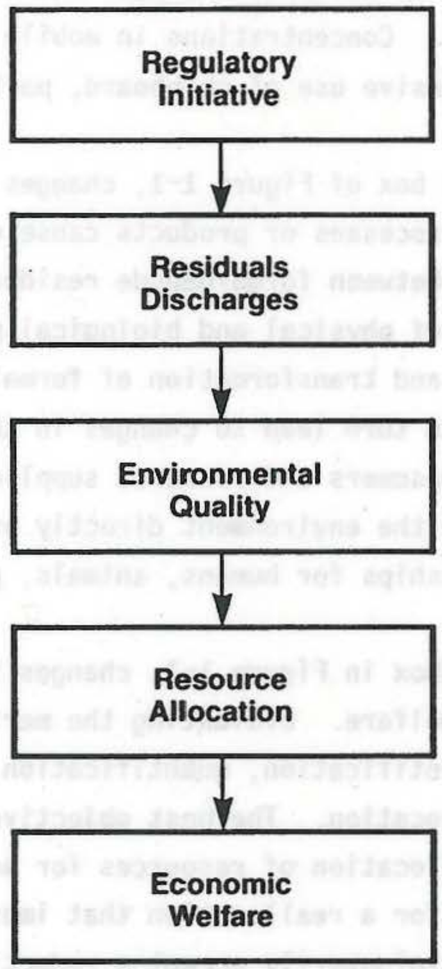


Figure 1-1. Effects of environmental policies.

depends on a number of product and environmental characteristics and declines with the age of the product. Concentrations in mobile homes may be especially significant due to the extensive use of chipboard, particle board, and plywood.

As shown in the second box of Figure 1-1, changes in formaldehyde residuals from production processes or products cause changes in environmental quality. The relationship between formaldehyde residuals and environmental quality reflects a variety of physical and biological processes affecting the transport, dispersion, and transformation of formaldehyde. Changes in environmental quality may in turn lead to changes in the activities of people in their roles as consumers and resource suppliers. These changes in activities are linked to the environment directly or indirectly with dose-response type relationships for humans, animals, plant life, and materials.

As shown in the final box in Figure 1-1, changes in resource allocation cause changes in economic welfare. Evaluating the merit of these changes to society requires the identification, quantification, and valuation of the changes in resource allocation. The best objective measure of the value of a change in the allocation of resources for an individual is his maximum willingness to pay for a reallocation that improves welfare or the minimum he would accept to voluntarily accept a reduction in welfare. This estimated value is, however, conditional on the distribution of income and the information available to the individual on the benefits and costs of alternative allocations of his scarce resources.

1.3 OBJECTIVES

As noted above, the overall goal of this study was to provide a preliminary assessment of the benefits of reducing human formaldehyde exposures. In particular, however, this study has four specific objectives:

- To summarize the extensive literature on the irritation and sensitization effects of formaldehyde exposures.
- To identify and estimate the population-at-risk from formaldehyde exposures.

- To provide preliminary evidence on the value of reductions in exposure.

- To identify the public and private responses to information on the health risks of formaldehyde exposure.

The following sections summarize the research conducted in support of these objectives.

1.4 FORMALDEHYDE EXPOSURE: THE EXTENT OF THE PROBLEM

One critical dimension to any regulatory evaluation is the extent to which the human population is exposed to the substance of concern. Since, as noted earlier, the most significant formaldehyde concentrations occur indoors--i.e., in the workplace or in the home--the extent of human formaldehyde exposure can be estimated based on the likely exposure of the workers and consumers who work and live, respectively, in environments that have significant formaldehyde concentrations. While this study focuses on consumers exposed in their homes, its results are extended to also infer the exposures of workers. Of particular concern, therefore, are the two primary sources of home formaldehyde exposure--UFFI and certain formaldehyde-containing wood products.

The first source of significant human formaldehyde exposure are the approximately 500,000 houses--most of which are older houses in the colder regions of the country--that contain UFFI. These houses were primarily retrofitted with UFFI in response to the rapid increase of energy prices after the oil embargo of 1973. UFFI was attractive because of its excellent insulating properties and because it can be installed with minimal structural disturbance. This use of UFFI peaked in the late 1970s. However as people learned of the pungent odor of UFFI and of the potential health effects of exposure to formaldehyde, the demand for UFFI fell. Today it no longer represents a significant share of the insulation exposure in the market. One dimension to the formaldehyde problem that public policy could address, therefore, is these existing sources of formaldehyde.

The second source of formaldehyde exposure in the home is the abundance of new formaldehyde-containing wood products. The major area of concern for these new sources are mobile homes, since large amounts of plywood, chipboard, and particleboard are used in their manufacture. Because they are relatively new (compared to UFFI), these products will likely require a regulation separate from a UFFI regulation to address their formaldehyde off-gassing problems.

1.5 FORMALDEHYDE EXPOSURE: A REVIEW OF THE HEALTH EFFECTS

A large number of studies have examined both the irritation and sensitization effects of formaldehyde exposure. Irritation describes the body's protective inflammation response to an unpleasant stimuli; sensitization is an acquired response to an unpleasant stimuli. With repeated exposure the body may become more or, in some cases, less sensitive to a given stimuli.

Conclusions of a causal relationship between formaldehyde exposure and adverse health effects must be based on the body of evidence evaluated by the following guidelines established by Sir Bradford Hill (Federal Panel on Formaldehyde, 1982):

- Biological plausibility
- Positive correlations between exposure and symptoms
- Strength of correlations between exposure and symptoms
- Reliability of results across cross-sections of population groups and conditions of exposure
- Temporal relationship between exposure and consequence
- Specificity of association between exposure and symptoms
- Identification of dose-response gradient.

Clinical and epidemiologic studies suggest that irritation effects from formaldehyde exposure may occur in humans, but many of the studies lack rigor and power in their investigation. This is especially true in the area of formaldehyde sensitization, where there is little evidence to support the presence of an immunologic mechanism in dermatitis or respiratory effects of the chemical. In evaluating the scientific evidence as a whole according to Hill's criteria, however, it does seem reasonable to conclude that formaldehyde can be considered a cause of various irritation effects.

The strength of the formaldehyde symptoms association is varied depending on organ involvement. The link is very strong for eye irritation, moderately strong for nasal irritation, and moderate for lung irritation. The causes of these irritation are multifactorial, with formaldehyde playing a role in the pathogenesis. Other chemical vapors, particulate materials such as dust and pollen, cigarette smoke, eye fatigue, and other factors also play an important role in discomfort due to eye irritation. Similarly, influenza virus infections, as well as the other factors mentioned contribute to upper and lower respiratory distress. The temporality of the formaldehyde-disease association is not well established, because it is usually not know if the consequence came before or after the purported cause. A dose-response gradient has been alluded to in many studies. Additional irritation and more severe consequences do result at higher concentrations of formaldehyde exposure.

This is also true in patch testing for hypersensitivity responses. A high dose of formalin will produce more positive reactions among the study subjects as well as more severe reactions individually. The biologic plausibility of the irritant effects of formaldehyde are well established from animal and controlled human studies. Immunologic mechanisms for formaldehyde sensitization are not as well defined.

The one criterion whose absence is most conspicuous is the lack of consistent results over varying populations employing varying methodologies. Additional study is desirable in potential high risk population groups such as newborns and very young children, the elderly, persons with preexisting respiratory diseases, and persons with certain allergies. Attention should be paid to low dose exposures and their effect in the highly susceptible individual. Other epidemiologic techniques such as the prospective study may be considered useful to examine these groups.

1.6 FORMALDEHYDE EXPOSURE: THE POPULATION AT RISK

For the purpose of identifying and estimating the population at risk, we have divided all houses and jobs into two formaldehyde concentration classes--high and low. As shown in Table 1-1, we estimate about 1.9 million workers are exposed to high concentrations of formaldehyde on the job. This represents about 1 percent of the population and 2 percent of the workforce. About 5.3 million people live in homes where they are subject to high exposures. This is less than 2 percent of the population. About 43,000 people may have high exposures to formaldehyde both on the job and in the home.

Profiles of exposure by time-of-day and day-of-week (weekday, weekend) in this study indicate the likely existence of rather large variations in exposure by population groups. No data are available to definitively identify exposure levels for population subgroups that may be especially sensitive to formaldehyde concentration. We suspect that there is some self-selection and that they are not proportionally distributed across exposure levels but not data an available to support this contention.

1.7 FORMALDEHYDE EXPOSURE REDUCTIONS: PRELIMINARY BENEFITS ESTIMATES

As discussed above, formaldehyde exposure may result in a number of acute health effects. A number of people are exposed to formaldehyde on the job or in the home. While reductions in exposure would obviously be welcomed by such individuals, for public policy purposes a measure of the value of such reductions would be useful. An objective measure of the value a change in the allocation of resources for an individual is his/her maximum willingness to pay for a reallocation that improves welfare or the minimum he/she would require to voluntarily accept a reduction in welfare. The estimated value is, however, conditional on the distribution of income and the information available to the individual on the benefits and costs of the reallocations.

A number of methods are available for identifying how individuals value the disutility of formaldehyde exposure or, alternatively, the benefits of reduced exposures. For this study we use a variant of the hedonic property value approach to develop some very preliminary estimates of these values. This approach assumes that the value of the quality of the indoor air for a house is reflected in the market price of the house. We developed a survey instrument and asked nine realtors in Connecticut, Wisconsin, and Washington to estimate the effect of UFFI on the price of recently exchanged houses with UFFI. A small sample size was used because of the time and resource constraints of the study.

Some realtors reported that houses with UFFI took longer to sell and sold for less than conventionally insulated homs. Specifically, the average reported difference in value was $5,044 or 6.5 percent for the 12 homes for which useful data were provided. This method is obviously not rigorous; the results are only suggestive. However, it is corroborated by anecdotal evidence from other realtors and appraisers. In addition, this number is in the lower range of the typical cost of removing UFFI. No similar study has been conducted for workers exposed on the job nor is any information available on the existence of wage premia, if any, for high exposure jobs.

To develop a crude aggregate estimate of the benefits of reducing all exposure to UFFI, we first calculated the annual value per household member. This value--which is based on assumptions regarding income and property taxes, the discount rate, and the average household size--is about $181 annually. Based on the estimated number of indviduals exposed as reported in Table 1-1 (5.250 million) consumers are willing to pay about $950 million annually to eliminate all formaldehyde in the home. To value reductions in occupational exposure we first scale the $181 value to reflect the average ratio of time spent on the job and in the home (0.41) to develop an estimate of the value per worker of $74 annually. Based on the number of workers occupationally exposed (1.863 million from Table 1-1), the estimated value to workers of a complete elimination of exposure to formaldehyde is $138 million annually. Together, the consumer and worker benefits total $1.1 billion annually. Obviously this is a very crude estimate of the value that would be obtained from a more comprehensive study. It is suggestive, however, that the benefits of reductions in exposure to formaldehyde may be significant.

Finally, it suggests that a more rigorous analysis of benefits may prove useful. Sufficient data of a reasonable quality are available, and the anecdotal evidence suggests that the size of the effect is large enough to justify using the more rigorous analysis.

1.8 FORMALDEHYDE EXPOSURE: PUBLIC AND PRIVATE SECTOR RESPONSES

Both the government and private sectors have responded as information has become available on the health effects of formaldehyde exposures. The Occupational Safety and Health Administration has promulgated an 8-hour

TABLE 1-1. EXPOSURE OF U.S. POPULATION TO FORMALDEHYDE (10^3)

Job	Home: Low exposure	Home: High exposure	Totals
No job	115,783	2,712	118,495
Low exposure	106,454	2,495	108,949
High exposure	1,820	43	1,863
Totals	224,057	5,250	229,307

time-weighted average exposure standard of 3 ppm with a ceiling of 5 ppm for the workplace. The Department of Housing and Urban Development (HUD) has proposed formaldehyde emission limits for plywood and particle board used is manufactured housing. In 1982 the Consumer Product Safety Commission (CPSC) banned the sale of UFFI. The ban was overturned in the courts. However, it raised the awareness of individuals in the public and private sectors of the potential effect of foam exposure. Other governmental responses at the national and state levels and in foreign countries have included product use standards, information disclosure requirements, and compensation schemes.

In the private sectors a number of responses have been identified. Specifically, suits have been filed against manufacturers and installers of formaldehyde--containing products--primarily UFFI. Public citizens and industry groups have sought to inform the public of the exposure risks and lobbied for legislation. Realtors, appraisers, and lenders have required homeowners to identify the presence of UFFI in houses they offer for sale. Buyers and sellers have tested for formaldehyde concentration in homes. Removal of UFFI or contaminant of the off-gases has been pursued in some places. Finally, producers have shifted away from formaldehyde in production processes.

1.5 REPORT ORGANIZATION

Chapter 2 summarizes the health effects literature on formaldehdye, concentration only on the possible irritation and sensitization effects. Chapter 3 develops estimates of exposure levels and the number of people exposed to formaldehyde and uses estimates of formaldehyde concentrations by place and time-place allocation studies for individuals in several population groups to identify and estimate the population at risk. Chapter 4 provides some very preliminary estimates of the compensation people require to risk exposure to formaldehyde in the home based on a small, nonrandom, opinion survey of realtors. The realtors were asked to provide estimates of the effect of the presence of UFFI on house prices. This information is used to develop aggregate estimates of the value of eliminating all exposures to formaldehyde. Finally, Chapter 5 discusses the public and private sector responses to the formaldehyde problem are discussed.

CHAPTER 2

IRRITATION AND SENSITIZATION EFFECTS OF FORMALDEHYDE EXPOSURES

Although exposure to formaldehyde may cause a variety of physical problems, this chapter summarizes only the acute and chronic minor health effects--irritation and systemic sensitization--reported in the literature. In particular, it summarizes the evidence on formaldehyde-exposure-induced irritation of the eyes, nose, and skin; of the respiratory and gastrointestinal tracts; and of the circulatory, central nervous, and reproductive systems. In addition, it also addresses the evidence on possible sensitization or allergic reactions to formaldehyde. It does not address the carcinogenic, mutagenic, and teratogenic effects, however. They are beyond the scope of this study.

The following sections define the specific acute and chronic minor health effects of formaldehyde exposure, describe the methodologies available for studying these health effects, and identify the population subgroups who may be at higher risk than others of suffering from formaldehyde exposure. Specifically, Section 2.1 provides working definitions of irritation and sensitization effects, and Section 2.2 describes the types of studies conducted to evaluate the association between these effects and formaldehyde, including guidelines to evaluate the scientific evidence about formaldehyde. Section 2.3 summarizes the reported evidence on irritation and sensitization effects of formaldehyde exposure, and Section 2.4 identifies portions of the population that may be especially sensitive to formaldehyde, including those who may experience more severe health consequences at a given concentration level and those who may exhibit health effects at concentration levels lower than those at which the general population may experience them.

2.1 THE PATHOLOGY OF IRRITATION AND SENSITIZATION

The two major health effects of formaldehyde to be discussed in this chapter are irritation and sensitization. A general definition and a description of these consequences are offered to set the stage for a more detailed description in later sections.

2.1.1 Irritation

Irritation is a generic term used to describe the body's reaction to an unpleasant stimuli. Excessive responsiveness to an adverse stimuli will produce discomfort and cellular changes. Overexcitation resulting in greater cellular and functional activity may be thought of as an irritation response (Dorland, 1974).

The irritation effects are dose- and time-related (Loomis, 1979). The response is a reaction to some threshold level of stimulus usually appearing contemporaneously with the administration of the stimulus. Symptoms often disappear upon removal of the stimulus. Additionally, most subjects, rather than a few exposed individuals, will experience the expected reaction when exposed at the toxic threshold levels (Consensus Workshop on Formaldehyde, 1983).

Loomis (1979) indicates that the average person exposed to concentrations of formaldehyde that are not subjectively discomforting would not be expected to experience irritant effects. The odor threshold for the detection of formaldehyde generally approximates the concentration of the chemical that is minimally active in producing irritant effects (Loomis, 1979; Thun et al., 1982). As the concentration of formaldehyde in the air increases, so does the degree of irritation (Loomis, 1979).

Two types of irritation may be caused by formaldehyde: sensor and inflammation (Consensus Workshop on Formaldehyde, 1983). Nucleophilic addition is suspected as the most important mechanism in sensory irritation, where formaldehyde reacts with SH and NH_2 groups in a reversible way (Consensus Workshop on Formaldehyde, 1983). Cellular damage and inflammation require several hours of exposure to occur and are characterized as is inflammation in other parts of the body (Consensus Workshop on Formaldehyde, 1983).

Irritation may be expressed differently in different parts of the body. Common types of irritation responses are lacrimation or tearing of the eyes, coughing, sneezing, and burning of the eyes, nose or throat (Consensus Workshop on Formaldehyde, 1983). All of these responses notify the brain of the presence of a noxious agent and serve to neutralize or rid the body of the chemical.

2.1.2 Sensitization

Sensitization is an "acquired, specific, altered capacity to react" (Consensus Workshop on Formaldehyde, 1983). Initial exposure, perhaps with little or no adverse outcomes, introduces a foreign substance or antigen to the body. The body reacts by forming antibodies to neutralize the activity of the antigen. On subsequent exposures to the antigen, a hypersensitivity response is mounted against the foreign substance. Antibodies previously created are called upon by the immune system to multiply and attack the antigen. This is known as an allergic reaction to an adverse stimuli, because the body calls into action circulating immune cells to detoxify the harmful agent. These immune cells recognize the foreign substance due to previous exposure to it (Dorland, 1974; Solomon, 1972).

Four different types of allergy can be induced (Consensus Workshop on Formaldehyde, 1983). The types vary by the reaction time, whether delayed or immediate, and by the mediator antibodies. The various sensitization responses may be composed of one or more types of allergic reaction.

Testing for sensitization is done through induction and challenge. Initial exposure is experienced in the induction phase. Subsequent exposures, usually at lower concentrations, represent the challenge. Reaction to the challenge after known induction is indication that sensitization to the substance being tested has occurred.

The intensity and nature of an immunogenic-mediated, or allergic, response may be so similar to a primary irritant response that a distinction from symptoms alone may not be possible (Loomis, 1979). The principal distinction between irritation and sensitization is the dose required to achieve the response. Reactions elicited at levels below those capable of inducing irritation responses are more likely to have been generated by an immune mechanism than any other type (Consensus Workshop on Formaldehyde, 1983; Loomis, 1979).

Other factors may distinguish sensitization responses. In many instances, subsequent exposure to formaldehyde at much lower concentrations than the initial exposure may elicit reactions (Small, 1982). Often, the reaction has a delayed onset relative to exposure, rather than a contemporaneous appearance. Only a subset of an exposed population is likely to experience sensitization (Consensus Workshop on Formaldehyde, 1983; Loomis, 1979).

2.2 METHODOLOGIES USED TO STUDY THE HEALTH EFFECTS OF FORMALDEHYDE

The three types of human studies commonly found in the health effects literature are all also found in the formaldehyde literature. These are: (1) case reports of persons with symptoms of formaldehyde exposure attended by a medical professional, (2) controlled experimental studies of subjects exposed to formaldehyde and, (3) epidemiological studies assessing the causal relationship between formaldehyde exposure and various health outcomes. Each type of study is summarized below, including descriptions of methods and the benefits and limitations of each design.

2.2.1 Case Reports

Isolated reports of disease occurrence are frequently published in the medical literature. These descriptive reports usually discuss interesting symptomology, difficult diagnoses, or new treatments of diseases.

Case reports provide clues of a possible exposure-disease relationship. However, they do not characterize the prevalence of the reactions in the general population, nor do they adequately summarize the range of observed reactions. Also, they do not represent a random selection of persons exposed to a substance such as formaldehyde who display symptoms.

2.2.2 Controlled Experimental Studies

Experimental human studies involve placing volunteers into environmentally controlled rooms and exposing participants to varying levels of a substance such as formaldehyde. These experiments are done usually on young male adults (aged 18 to 25 years), who are paid for their services.

The participants are typically required to be healthy, usually meaning free of respiratory disease and allergies. Investigator-controlled amounts of formaldehyde are pumped into the chambers for a period of time and outcomes are recorded. The disease endpoints, usually odor, eye, skin, and nasal irritation, may be reported by the subject or objectively measured by the investigator. An example of an objective measurement of eye irritation is the number of blinks per minute or redness of eyes. Sometimes a control group is studied in a chamber pumped with ambient air, for comparison (NRC, 1981; Federal Panel on Formaldehyde, 1982).

A dose-response gradient may be developed from this type of study. The prevalence of each health effect can be plotted at various concentrations of the substance. Threshold levels where consequences of exposure are first noticed can be detected using this experimental design. The investigator is at liberty to vary concentration, duration, and agents under these controlled procedures.

The limitations of these studies primarily lie in their small, restricted sample. It is impossible to generalize beyond the demographics of the chosen participants. For example, since white males aged 18 to 25 make up the study population for most of these studies, one cannot predict with any degree of certainty the response to formaldehyde in women, blacks, or persons aged less than 18 or greater than 25 years from such controlled experimental studies. Also totally unknown are the adverse effects of formaldehyde in persons who have chronic diseases, allergies, or hyperreactive airways. Also, the small number of participants in each controlled study may result in imprecise estimates of the magnitude of the associations between symptoms and exposure.

2.2.3 Epidemiological Studies

The majority of studies of formaldehyde found in the health literature attempt to measure the association between a series of common symptoms and formaldehyde exposure using an epidemiological study design. Ascertainment of disease outcomes, usually by survey, and measurement of chemical exposure, usually determined by presence or absence of the chemical, or by measuring dose concentration, are done at the same point in time. For example, in an occupational study employees fill out questionnaires about contact with formaldehyde on the job and a check list of symptoms. Comparisons of the prevalence of symptoms are made. Symptoms in persons working with formaldehyde are tabulated. Another example is a study of residents known to have had formaldehyde exposure from urea-formaldehyde foam insulation (UFFI). Questionnaires about illnesses during that exposure are answered by the participants.

Among the many types of epidemiological study designs, two stand out as the most appropriate for the study of formaldehyde health effects. These are the cross-sectional and prospective cohort types of studies. These studies are discussed in their simplest forms, to address the basic methods utilized for scientific research.

The cross-sectional design captures the moment when an exposure to formaldehyde can be identified in a group studied. Collection of disease and exposure information is done simultaneously. This method is quite useful when the disease endpoint is common to many group members and easily reported. This study design lacks temporal information about the disease, since it includes persons diseased and disease-free at the moment of exposure. It is only those people who are disease-free who can report true formaldehyde-related illness. Both internal or external control groups can be used. For example, exposed workers in a plant can be compared to other plant employees with no exposure (internal controls). Cohorts of exposed persons can be compared to geographically distinct unexposed groups (external controls).

Most cross-sectional symptom reports are elicited from a self-selected group of persons. These people may be different than the general population in that they may be more likely to report formaldehyde-related symptoms to a doctor or state health department, more likely to have installed UFFI in their homes, more sensitive to formaldehyde exposure, or more educated about the relationship between formaldehyde and these symptoms. These studies may report an exaggerated relationship between the chemical and the symptoms.

The prospective cohort design is used to study disease-free cohorts of exposed and nonexposed persons. These subjects are followed over a predetermined period of time to record their health status. The incidence of a number of endpoints in the exposed and unexposed groups is then compared. For example, if formaldehyde causes asthma in a prospective cohort study, one would expect a higher rate of asthma in the group exposed to formaldehyde. In the simplest analysis, we would know that there were no other predisposing conditions because the participants were disease-free at the point of entry to the study (reporting no history of asthma). One would screen out individuals having allergies, respiratory difficulties, etc., or control for these effects, for a clean test of the hypothesis that formaldehyde caused the condition in the subject.

2.2.4 Evaluating the Evidence

A large body of scientific evidence on the irritation and sensitization effects of formaldehyde exposure is summarized in Section 2.3. These studies are of the types described above. They use clinical and epidemiologic methods to investigate the causal association between formaldehyde and a variety of irritation and allergic effects.

As with most toxicological investigations, studies of formaldehyde do not provide enough information to answer all questions with complete confidence. Since formaldehyde may generate reactions through both irritation and sensitization, and since the pathways for these reactions are not completely understood, no completely safe level of exposure exists for the entire population (Loomis, 1979).

Loomis (1979) recommended that establishment of thresholds be based on the best information available, keeping in mind the probability that the laws of biological variation will apply. This means that some individuals will display hypersensitivity and some hypertolerance at each end of any range of "safe" concentrations established, no matter what the ranges. Properly complete and extensive studies provide necessary information to establish ranges for which an acceptable number of individuals will be protected from adverse effects.

No one study has established the suspected relationship between formaldehyde and the various reactions reported. More and better studies for detection of thresholds for irritation effects and for identification of mechanisms for sensitization have been recommended (Consensus Workshop on Formaldehyde, 1983; Loomis, 1979). The best studies available should be identified, and an evaluation of that body of studies should be made from which conclusions may be derived.

Conclusions of a causal relationship between formaldehyde and adverse health effects must be based on the body of evidence evaluated by the following guidelines established by Sir Bradford Hill (Federal Panel on Formaldehyde, 1982):

- Biological plausibility
- Positive correlations between exposure and symptoms
- Strength of correlations between exposure and symptoms
- Reliability of results across cross-sections of population groups and conditions of exposure
- Temporal relationship between exposure and consequence
- Specificity of association between exposure and symptoms
- Identification of dose-response gradient.

Biological plausibility means that experimental evidence obtained from animal or human studies suggests that a chemical, such as formaldehyde, is capable of producing cellular damage resulting in exhibited symptoms. Establishing biological plausibility only implies that a relationship between a suspected stimulus and adverse effects are possible, not necessarily that they are probable.

Positive correlations between formaldehyde exposure and a variety of symptoms provide a more definite indication of their relationship. The strength of these correlations is important in that the stronger the observed relationship, the more confidence an experimenter has in the conclusions. If the results are reliable, they may be replicated by other experimenters using the same methodology. Consistent results obtained using various study designs and in many population groups (across races, countries, sexes) provide strong support for concluding that a relationship exists between a chemical and a health effect.

A temporal relationship should be established between exposure to formaldehyde and suspected consequences in order to rule out preexisting conditions. A complicating factor may be the duration of this temporal relationship. Causality becomes more difficult to establish when a long period of time passes between exposure and symptomatic reactions.

Specificity of association is evidence of a causal relationship. It may be indicated if formaldehyde is linked to a single specified adverse effect. The association is strengthened if the chemical may be identified as the only known cause for the symptoms.

The determination of a dose-response gradient provides more specific evidence of the relationship between formaldehyde exposure and adverse health responses. The response should be more pronounced at higher doses of the chemical. A threshold may be established below which no effects are observed. Identification of this gradient establishes that a concrete relationship does exist.

2.3 HEALTH EFFECTS OF FORMALDEHYDE

Exposure pathways for formaldehyde include inhalation, ingestion, and dermal or sensory contact. Various senses and organs of the body may be affected upon exposure. The responses and the associated formaldehyde concentrations reported are described in this section.

This section outlines the effects of formaldehyde exposure. It is important to note that the summary data presented are not inclusive of every study and all literature available on formaldehyde. An effort has been made to include most of the major studies, surveys, and case reports conducted.

Interpretation of the data is subject to the limitations of the studies and reviews contained therein. Conclusions supported by the majority of studies are discussed, rather than each individual report. Some counter-studies are mentioned, where available.

2.3.1 Eye Effects

Table 2-1 describes eye effects which have been reported for formaldehyde exposure. Eye effects are due to irritation, rather than to sensitization. They include general irritation, tearing (lacrimation), stinging, redness, prickling, conjunctivitis, changes in eye sensitivity, reversible tissue damage, retinal edema, and blindness (when splashed directly into eyes).

TABLE 2-1. REPORTED EYE EFFECTS OF FORMALDEHYDE EXPOSURE

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.01	5 minutes	Human	Irritation	Schuck et al. (1966)[a]
0.02 - 4.15	Residential	Human	Irritation	Woodbury (1979);[a] Breysse (1977);[a] Sardinas et al. (1979);[a] Garry et al. (1980);[a] Harris et al. (1981);[a] Wisconsin Division of Health (1978)[b]
0.03 - 2.5	Residential	Human	Irritation	Breysse (1978)[b]
0.03 - 3.2	20-30 minutes, gradual increase in concentration	Human	Increase in blink rate; Irritation	Wayne et al. (1976)[b]
0.04 - 1.25	Occupational - chipboard makers	Human	Irritation in 74 percent of 47 subjects	Alexandersson et al. (1982)
0.05	Minutes	Mouse	Irritation	Kane and Alarie (1977)[c]
0.05 - 0.50	5 minutes	Human	Irritation in unacclimated	Schuck et al. (1966)[d]
0.067 - 4.82	Residential	Human	Tearing	Wisconsin Division of Health (1978)[b]
0.08	1.5 months	Rabbit	Changes in evoked potential of optic nerve	Bokina et al. (1976)[a]
0.08 - 5.26	Occupational - embalmers	Human	Burning	Kerfoot and Mooney (1975)[a,c,d,e,f]

See footnotes at end of table. (continued)

TABLE 2-1 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.12 - 0.46	Occupational	Human	Burning; Stinging	Bourne and Sefarian (1959)[a]
0.12 - 1.60	Occupational/Residential - office in mobile homes	Human	Irritation	Hogan and Main (1983)
0.13 - 0.45	Occupational - wood processing workers	Human	Stinging; Burning	Wayne et al. (1976)[b]
0.13 - 0.45	?	Human	Temporary irritation	Walker (1966)[d]
0.13 - 0.45	Occupational - textile workers	Human	Intolerable irritation	Bourne and Sefarian (1959)[g]
0.20	1 hour	Human	Irritation	Rader (1974)[a]
0.25	5 hours/day, 4 days	Human	Slight discomfort in 19 percent of sample	Andersen (1979)[b]
0.30 - 0.50	5 minutes	Human	Increased blink rates proportional to concentration	Schuck (1966)[d]
0.30 - 2.7	Occupational - textile workers	Human	Prickling; Heavy tearing	Shipkovitz (1968)[b,d]
0.35 - 1.0	6 minutes	Human	Irritation	Bender et al. (1983)

See footnotes at end of table. (continued)

TABLE 2-1 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.40 - 0.80	Occupational - phenol-formaldehyde resin workers	Human	Irritation	Schoenberg and Mitchell (1975)[g]
0.42	5 hours/day, 4 days	Human	Slight discomfort in 31 percent of sample; Conjunctival irritation	Andersen (1978)[b]
0.8	Daily	Human	Irritation in most sensitive individuals	Zaeva et al. (1968)[d]
0.83	10 minutes	Human	Irritation	Sgibnev (1968)[a]
0.83 - 1.6	5 hours/day, 4 days	Human	Slight discomfort in 94 percent of sample; Conjunctival irritation	Andersen (1978)[b]
0.9 - 1.6	Occupational - physician	Human	Intense irritation and itching in one subject	Porter (1975)[b,d]
0.9 - 2.7	Occupational - textile garment workers	Human	Tearing	Blejer and Miller (1966)[b,d]
0.9 - 3.3	Occupational - clothing store workers	Human	Mild irritation	Miller and Blejer (1966)[d]

See footnotes at end of table. (continued)

TABLE 2-1 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.92 - 1.58	Occupational - paper-conditioning workers	Human	Itching	Morrill (1961)[a,d]
1.0 - 11.0	Occupational - nylon fabric workers	Human	Irritation	Ettinger and Jeremias (1955)[d]
1.1 - 2.3	Occupational	Human	Slight discomfort	Snell (1979)
1.42	1 minute	Human	Eye sensitivity to light lowered in unacclimated group	Melekhina (1964)[a,d]
2.0 - 3.0	Occupational	Human	Mild irritation	Zenz, ed. (1980)[h]
2.4 - 5.2	Occupational	Human	Definite discomfort	Snell (1979)
4.0	?	Human	Increased incidence of catarrhal conjunctivitis	Commercial Solvents Corporation (unpublished)[d]
4.0 - 5.0	Occupational	Human	Irritation; Lacrimation; Discomfort in 30 minutes	Fassett (1963)[b]
5.3 - 9.0	Occupational	Human	Pain at tolerable level	Snell (1979)
Above 9.0	Occupational	Human	Pain interferes with work	Snell (1979)

See footnotes at end of table. (continued)

TABLE 2-1 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
10.0	Occupational	Human	Pronounced lacrimation; Pain intolerable without protection	Zenz, ed. (1980)[h]
10.0 - 30.0	1 minute	Human	Tingling in hypersensitive worker	Harris (1953)[d]
13.8	30 minutes	Human	Irritation; Development of tolerance after 10 minutes	Sim and Pattle (1957)[b,d]
16.0 - 30.0	Occupational - resin production workers	Human	Irritation	Glass (1961)[d]
20.0	Less than 1 minute	Human	Discomfort; Lacrimation	Barnes and Speicher (1942)[b]
25.0 - 50.0	?	Human	Reversible tissue damage	Clayton and Clayton, ed. (1981)[h]
40.0 - 70.0	10 days	Ginea pig, rabbit	Marked irritation; No corneal damage	Fielder (1981)[i]
0.074%, 0.092% formadehyde in aqueous solution	Contact with cosmetic products	Rabbit	Minimal irritation	Cosmetic, Toiletry, and Fragrance Association (1981)[h]

See footnotes at end of table. (continued)

TABLE 2-1 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
15.0% formaldehyde in aqueous solution	Vapor	Rabbit	Severe irritation; Corneal and conjunctival edema	Carpenter and Smyth (1946)[b]
40% formaldehyde in aqueous solution	Accidental splash contact	Human	Worker blinded upon failure to rinse eyes	Kelecom (1962)[b]
0.9 g/kg	Intravenous injection	Human	Retinal edema	Potts (1955)[b]
?	Residential	Human	Burning in 18 of 1396 subjects (nonsignificant)	Thun et al. (1982)
?	Residential	Human	Irritation in 172 of 256 subjects; Burning in 152 of 256 subjects	Dally et al. (1981)
?	Occupational - embalmers	Human	Irritation	Plunkett and Barbella (1977)[c]
?	Occupational - polyethylene thermocutters	Human	Burning; Irritation	Hovding (1969)[d]

See footnotes at end of table. (continued)

TABLE 2-1 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
?	Occupational - permanent press textile workers	Human	Catarrhal conjunctivitis in 72% of sample	Kratochvil (1971)[d]

[a]Cited in Gupta, K. C., A. G. Ulsamer, and P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Sources and Toxicity." Environment International 8:349-358.

[b]Cited in National Research Council, 1981. Formaldehyde and Other Aldehydes. Washington, D. C.

[c]Cited in Loomis, T. A., 1979. "Formaldehyde Toxicity." Archives of Pathological Laboratory Medicine 103:321-324.

[d]Cited in National Institute of Occupational Safety and Health, 1976. Criteria for a Recommended Standard . . . Occupational Exposure to Formaldehyde. DHEW (NIOSH) Publication No. 77-126. Washington, D. C.: Department of Health, Education, and Welfare.

[e]Cited in Federal Panel on Formaldehyde, 1982. "Report of the Federal Panel on Formaldehyde." Environmental Health Perspectives 43:139-168.

[f]Cited in Bardana, Emil J., 1980. "Formaldehyde: Hypersensitivity and Irritant Reactions at Work and in the Home." Immunology and Allergy Practice II(3):11-23.

[g]Cited in Main, David M., and Theodore J. Hogan, 1983. "Health Effects of Low-Level Exposure to Formaldehyde." Journal of Occupational Medicine 25(2):896-900.

[h]Cited in Wartew, G. A., 1983. "The Health Hazards of Formaldehyde." Journal of Applied Toxicology 3(3):121-126.

[i]Cited in Cosmetic Ingredient Review, 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology 3(3):157-184.

A minimum threshold to eye effects has been shown to be 0.01 ppm gaseous exposure in the presence of other pollutants (Schuck et al., 1966). Bender et al. (1983) found that eye irritation occurs at formaldehyde concentrations between 0.4 ppm and 1.0 ppm, agreeing with several other studies.

The dose-response relationship between concentration of formaldehyde and time to response has been established at levels above the threshold of response. Bender et al. (1983) noted a significant relationship at 1.0 ppm and suggested that such a relationship exists for levels as low as 0.7 ppm. Andersen (1978) observed a correlation between concentration and response above 0.8 ppm. Schuck et al. (1966) found linear dose-response relationships for formaldehyde over a range of 0.3 ppm to 1.0 ppm in combination with ethylene oxidation products and with propylene oxidation products.

An increase in severity was observed as concentrations of formaldehyde increased, though the response was not consistent for all levels of exposure tested (Bender et al., 1983; Andersen, 1978). In combination with other pollutants, the same level of irritation was observed at formaldehyde concentrations from 0.05 ppm to 0.50 ppm (Schuck et al., 1966).

Subjects usually report irritation in residential settings at lower concentrations of formaldehyde than do subjects exposed occupationally. This may be due to a greater amount of time spent in the home than in an occupational environment (see Section 3.2), so that more opportunity for observation of the formaldehyde effect exists.

Alternatively, there is evidence that individuals develop tolerances in eye sensitivity based on the duration of exposure to formaldehyde (Sim and Pattle, 1957; Bender et al., 1983). Workers are more likely to experience exposure concentrations and durations at higher levels than persons in residences, so they will more likely have a higher tolerance level than will homeowners.

Formaldehyde concentrations in the occupational and residential environments are usually measured after complaints have been registered with employers or State Health Departments. Comparisons are made with nonexposed persons, or with persons exposed at much lower concentrations, rather than at controlled dosages. Though less precise, the results of these studies are indicative of effects experienced in environments where exposures may fluctuate throughout duration of exposure.

Workers in textile manufacturing, garment manufacturing, clothing sales, wood processing (chipboard, plywood, and particleboard), formaldehyde resin manufacturing and use, polyethylene thermocutting, embalming, and other industries using formaldehyde and formaldehyde products have reported eye irritation symptoms due to formaldehyde exposure (Alexandersson et al., 1982; Kerfoot and Mooney, 1975; Wayne et al., 1976; Shipkovitz, 1968; Schoenberg and Mitchell, 1975; Blejer and Miller, 1966; Miller and Blejer, 1966; Morrill, 1961; Ettinger and Jeremias, 1955; Glass, 1961; Hovding, 1969; Kratochvil, 1971; Plunkett and Barbella, 1977; Zenz, 1980; Fassett, 1963; Snell, 1979; Bourne and Sefarian, 1959).

Blindness resulted in an occupational accident in which formaldehyde solution was splashed into a worker's eyes. A coworker who received the same injury had his sight saved by immediate flushing with water (Kelecom, 1962).

Visual function tests including tests of visual acuity, depth perception, peripheral perception, eye movement and fixation, color vision, accommodation facility, divided attention, dynamical acuity, and acuity with glare were performed on workers in a wood processing plant (Wayne et al., 1976). Wayne et al. found that performance of the visual tasks did not differ significantly between subjects exposed to high and low concentrations of formaldehyde. No association between reported eye irritation and performance on the visual function tests was found. No significant dose-response relationship between irritation and formaldehyde concentration was noted.

These results indicate the presence of eye irritation is expected to have little effect on the ability of the subject to perform his or her work at low concentrations. At higher concentrations (above 9.0 ppm), some workers report intolerable pain (Snell, 1979; Zenz, 1980). However, development of tolerance after 10 minutes of exposure was noted at 13.8 ppm (Sim and Pattle, 1957), and only irritation was reported at levels as high as 16.0 ppm to 30.0 ppm (Glass, 1961). It is possible that tolerance to formaldehyde occurs in many occupational environments, and also that presence of some other irritant in combination with formaldehyde is responsible for severe irritation at lower concentrations.

Symptoms of exposure have been noted in residential settings, particularly in homes containing urea-formaldehyde foam insulation (UFFI) and furnishings which emit formaldehyde, and in mobile homes which use large amounts of formaldehyde-emitting products (Woodbury, 1979; Breysse, 1977; Sardinas et al., 1979; Garry et al., 1980; Harris et al., 1981; Wisconsin Division of Health, 1978; Hogan and Main, 1983; Dally et al., 1981; Thun et al., 1982). The burning, stinging, and tearing reported usually disappeared when individuals left the exposure environment (Hogan and Main, 1983; Dally et al., 1981).

2.3.2 Nose, Throat, and Upper Airway Effects

Reported effects of the nose, throat, and upper airway due to formaldehyde exposure are reported in Table 2-2. These effects include burning and stinging of the nose and throat, running nose, sneezing, dryness and soreness of the throat, diminished smell, general irritation, and inflammation. Often these effects are associated with eye irritation, and with noticeable odor (NRC, 1981; Dally et al., 1981; Loomis, 1979).

The odor threshold has been defined in two ways (Leonardos et al., 1969). One definition is the minimum identifiable odor or recognition threshold, which requires distinct identification of the chemical. The other definition requires a detectable difference from background odors.

Using the recognition threshold definition, Leonardos et al. (1969) found the threshold for four trained panelists to be 1.0 ppm. This concentration is also quoted by Zenz (1980). Snell (1979), using the second definition, determined a threshold in occupational environments of 0.8 ppm to 1.7 ppm. Thresholds as low as 0.04 (Freeman and Grendon, 1971), 0.05 (Wahren, 1980; Melekhina, 1964; Feldman and Bonashevskaya, 1971), and 0.07 (Walker, 1966) have been noted. Longer periods of exposure were necessary to elicit odor threshold at the lower concentrations (Freeman and Grendon, 1971).

Irritation such as dryness of nose and throat, thirst, prickling, burning, and stinging of the nose, soreness of the throat, and sneezing may

TABLE 2-2. REPORTED NOSE, THROAT, AND UPPER AIRWAY EFFECTS OF FORMALDEHYDE EXPOSURE

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.02 - 4.17	Residential	Human	Upper respiratory tract irritation	Woodbury (1979)[a]; Breysse (1977);[a] Sardinas et al. (1979);[a] Garry et al. (1980);[a] Harris et al. (1981)[a]
0.03 - 2.54	Residential	Human	Sore throat and hoarseness in 63 percent of 92 subjects; Rhinorrhea, sneezing, tingling of nostril in 13 percent of 92 subjects	Breysse (1977)[b]
0.04 - 1.25	Occupational - chipboard makers	Human	Nose and throat irritation in 36 percent of 47 subjects	Alexandersson et al. (1982)
0.04 - 8.0	Occupational - laminating plant workers	Human	Odor threshold	Freeman and Grendon (1971)[c]
0.05	Occupational - resin production workers	Human	Runny nose	Gamble et al. (1976)[b,d]
0.05 - 0.06	Minutes - odor panels, EEG activity monitor	Human	Odor threshold	Wahren (1980);[a] Melekhina (1964);[a,d] Feldman and Bonashevskaya (1971)[a]
0.07	1 minute	Human	Odor threshold for group of 15 subjects	Walker (1966)[c]

See footnotes at end of table. (continued)

TABLE 2-2 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.08 - 5.58	Occupational - embalmers	Human	Burning of nose; Sneezing	Kerfoot and Mooney (1975)[a,c]
0.12 - 0.46	Occupational - dress shop workers	Human	Burning and stinging of nose and throat; "Suffocating" odor	Bourne and Seferian (1959)[a,c,e]
0.12 - 1.6	Occupational/ Residential - office in mobile home	Human	Throat and nose irritation	Hogan and Main (1983)
0.13 - 0.45	?	Human	Upper respiratory tract irritation	Walker (1966)[c]
0.20	1 hour	Human	Nose and throat irritation	Rader (1974)[a]
0.25 - 1.39	Occupational - embalmers	Human	Upper respiratory tract irritation	Kerfoot and Mooney (1975)[c,d,e,f]
0.25,0.42,1.6	5 hours/day, 4 days	Human	Dryness of nose and throat; Decrease in mucous flow rate	Andersen (1979)[a,f]

See footnotes at end of table. (continued)

TABLE 2-2 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.30 - 2.75	Occupational	Human	Annoying odor; Constant prickling of mucous membranes; Thirst	Shipkovitz (1968)[a,c]
0.40 - 0.80	Occupational - resin production workers	Human	Nose irritation	Schoenberg and Mitchell (1975)[d]
0.5 - 7.3	Occupational - wood processing workers	Human	Upper respiratory irritation in 129 of 278 workers	Yefremov (1970);[c] Zaeva et al. (1968)[c]
0.50 - 8.9	Occupational - wood processing workers	Human	Throat irritation; diminished smell; dryness ofthe nose and throat; pharyngitis; chronic rhinitis	National Institute of Occupational Safety and Health (1976)[f]
0.8 - 1.7	Occupational	Human	Odor barely detectable	Snell (1979)
0.83	Occupational, greater than 5 years to less than 10 years	Human	Loss of olfactory sense; Increased upper respiratory disease	Yefremov (1970);[a,d] Zaeva et al. (1968)[c]
0.83	10 minutes	Human	Upper respiratory tract irritation	Sgibnev (1968)[a,c]

See footnotes at end of table. (continued)

TABLE 2-2 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.83	10 months over 2 generations	Rat	Morphological changes in upper respiratory tract	Misiakiewicz et al. (1977)[a]
0.90 - 2.7	Occupational - garment factory workers	Human	Nose and throat irritation	Blejer and Miller (1966)[a,c,e]
0.90 - 1.6	Occupational - clothing store workers	Human	Odor objectionable	Miller and Blejer (1966)[c]
0.92 - 1.58	Occupational - paper conditioning workers	Human	Dry and sore throats; Unusual thirst upon waking	Morrill (1961)[a,c]
1.0	Odor panel	Human	Odor threshold for 4 panelists	Leonardos et al. (1969)[c]
1.0	Occupational	Human	Odor threshold for most people	Zenz, ed. (1980)[e]
1.0	Occupational - laminating plant workers	Human	Odor objectionable	Freeman and Grendon (1971)[c]
1.0 - 11.0	Occupational - nylon fabric workers	Human	Nose and throat irritation	Ettinger and Jeremias (1955)[c]
1.8 - 3.0	Occupational	Human	Odor clearly detectable, but tolerable	Snell (1979)

See footnotes at end of table. (continued)

TABLE 2-2 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
2.0 - 3.0	Occupational	Human	Mild nose and throat irritation	Zenz, ed. (1980)[e]
3.1 - 5.2	Occupational	Human	Odor almost intolerable	Snell (1979)
4.0	?	Human	Nasopharyngeal irritation	Commercial Solvents Corporation (unpublished)[c]
4.17 - 10.9	1 minute	Human	Odor unbearable without respiratory protection	Wiley (1908)[a,c]
4.2 - 10.9	Occupational - laminating plant	Human	Odor unbearable without respiratory protection	Freeman and Grendon (1971)[c]
5.0	Occupational - teachers and students in pre-fab school	Human	Respiratory tract irritation; Increased thirst; Strong odor	Helwig (1977)[f]
5.3 and above	Occupational	Human	Odor intolerable	Snell (1979)
8.07	60 days	Rat	Respiratory tract irritation	Dubreuil et al. (1976)[f]
13.8	30 minutes (smog chamber)	Human	Nose irritation; Development of tolerance after 10 minutes	Sim and Pattle (1957)[c]

See footnotes at end of table. (continued)

TABLE 2-2 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
16.0 - 30.0	Occupational - resin production workers	Human	Throat irritation	Glass (1961)[c]
41.67	1 hour/day, 3 days/week, 35 weeks	Mouse	Upper respiratory tract inflammation	Horton et al. (1963)[a]
211.0 - 667.0	3.5 - 4 hours	Cat	Irritation of mucous membranes with recovery in 2 days	Iwanoff (1911)[c]
?	Occupational - clothing production workers	Human	Catarrhal inflammation of upper respiratory tract in 28 percent of 18 subjects; Inflammatory rhinitis in 28 percent of 18 subjects	Kratochvil (1977)[c,d]
?	Occupational - embalmers	Human	Nose and throat irritation in 75 percent of 57 subjects	Plunkett and Barbella (1977)[f]
?	Occupational - polyethylene thermocutters	Human	Dryness and irritation of the nose and throat	Hovding (1969)[c]
?	Residential	Human	Sore throat in 32 of 1,396 subjects (nonsignificant); runny nose in 15 of 1,396 subjects (nonsignificant)	Thun et al. (1982)

See footnotes at end of table. (continued)

TABLE 2-2 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
?	Residential	Human	Runny nose in 151 of 256 subjects; Dry or sore throat in 145 of 256 subjects	Dally et al. (1981)

[a]Cited in Gupta, K. C., A. G. Ulsamer, and P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Sources and Toxicity." Environment International 8:349-358.

[b]Cited in Bardana, Emil J., 1980. "Formaldehyde: Hypersensitivity and Irritant Reactions at Work and in the Home." Immunology and Alergy Practice II(3):11-23.

[c]Cited in National Institute of Occupational Safety and Health, 1976. Criteria for a Recommended Standard . . . Occupational Exposure to Formaldehyde. DHEW (NIOSH) Publication No. 77-126. Washington, D. C.: Department of Health, Education, and Welfare.

[d]Cited in Federal Panel on Formaldehyde, 1982. "Report on the Federal Panel on Formaldehyde." Environmental Health Perspectives 43:139-168.

[e]Cited in Wartew, G. A., 1983. "The Health Hazards of Formaldehyde." Journal of Applied Toxicology 3(3):121-126.

[f]Cited in National Research Council, 1981. Formaldehyde and Other Aldehydes. Washington, D. C.

[g]Cited in Loomis, T. A., 1979. "Formaldehyde Toxicity." Archives of Pathological Laboratory Medicine 103:321-324.

occur at very low concentrations of formaldehyde, from 0.2 ppm to 0.8 ppm. These symptoms have been observed in both residential and occupational settings (Woodbury, 1979; Breysse, 1977; Sardinas et al., 1979; Garry et al., 1980; Harris et al., 1981; Alexandersson et al., 1982; Gamble et al., 1976; Kerfoot and Mooney, 1975; Bourne and Seferian, 1959; Hogan and Main, 1983; Walker, 1966; Rader, 1974; Shipkovitz, 1968; Schoenberg and Mitchell, 1975; Yefremov, 1970; Zaeva et al., 1968; Plunkett and Barbella, 1977; Thun et al., 1982; Dally et al., 1981).

At somewhat higher concentrations (0.8 ppm to 1.0 ppm), the sense of smell is diminished, the odor becomes objectionable, and morphological changes in the upper respiratory tract take place (Yefremov, 1970; Zaeva, 1968; Misiakiewicz et al., 1977). Symptoms are noticed at increasingly higher concentrations, as the odor becomes more noticeable, and finally, unbearable at levels around 4.2 ppm and 5.3 ppm (Freeman and Grendon, 1971; Wiley, 1908; Snell, 1979).

Other researchers have found that irritation is first experienced at much higher levels, from 13.8 ppm to 30.0 ppm (Sim and Pattle, 1957; Glass, 1961). These individuals were determined to have developed tolerance for lower levels due to occupational exposure (Sim and Pattle, 1957; Glass, 1961). The National Research Council (1981) concluded that some effects may be felt at very low concentrations, but frequency of complaints is noted at concentrations between 1.0 and 11.0 ppm.

More severe symptoms, such as inflammation of the upper respiratory tract, have been observed in test animals at even higher concentrations of formaldehyde, around 41.0 ppm and above (Horton et al., 1963; Iwanoff, 1911). Inflammation has also resulted in the occupational setting for cothing production workers (Kratochvil, 1971).

2.3.3 Pulmonary Effects

Table 2-3 outlines the reported pulmonary effects due to formaldehyde exposure. These effects are related to breathing functions and include cough, shortness of breath, chest tightness, wheezing, inflammation of the respiratory organs, pulmonary edema, pneumonitis, alterations in respiratory rate, and asthma.

TABLE 2-3. REPORTED PULMONARY EFFECTS OF FORMALDEHYDE EXPOSURE

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.04 - 1.25	Occupational - chipboard makers	Human	Chest oppression in 10 percent of 47 subjects; Cough in 4 percent of 47 subjects; Reduced expiratory volume; Increased closing volume; Bronchioconstriction	Alexandersson et al. (1982)
0.05	Occupational - resin production workers	Human	Cough; Chest tightness; Decreased pulmonary function due to respirable particles	Gamble et al. (1976)[a,b]
0.08 - 5.58	Occupational	Human	Cough; Asthma or sinus problems in 3 of 5 subjects	Kerfoot and Mooney (1975)[c]
0.12 - 1.6	Occupational/ Residential - office in mobile home	Human	Shortness of breath; Chest tightness	Hogan and Main (1983)
0.3 - 2.7	Occupational - permanent press textile workers	Human	Wheezing	Shipkovitz (1968)[d]
0.33	1 hour	Guinea pig	Decrease in respiration; Increase in compliance	Amdur (1959)[c]
0.40	Occupational - resin users	Human	Chronic cough; Sputum production; Reduction in airflow	Schoenberg and Mitchell (1975)[e]

See footnotes at end of table. (continued)

TABLE 2-3 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.56	10 minutes	Rat	Reduction in respiratory rate	Kane and Alarie (1977)[c]
0.83, 2.5	90 days	Rat	Peribronchial and perivascular hyperemia; Lymphohistiocytic proliferation in lungs	Feldman and Bonashevskaya (1971)[c,d]
0.83	10 minutes	Human	Accelerated breathing	Sgibnev (1968)[c]
1.67	Continuous or intermittent	Guinea pig, rat	Sensitization	Ostapovich (1975)[c]
3.1(induction), 0.55 - 13.4 (challenge)	10 minutes/hour, 3 hours/day, 3 days	Mouse	Increase in airflow resistance; Development of tolerance during exposure period; Symptoms reappear on challenge	Kane and Alarie (1977)[e]
3.5	1 hour	Guinea pig	Increase in airflor resistance; Decrease in compliance	Amdur (1960)[e]
3.5	18 hour exposure to vapor	Rat	Inactivation of cilia in bronchial tree	Murphy et al. (1964)[b]
3.83 - 5.0	90 days continuous	Rat, dog rabbit, monkey, guinea pig	Inflammation of lungs in all species; Death in 1/15 rats	Coon et al. (1970)[c,f]

See footnotes at end of table. (continued)

TABLE 2-3 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
3.9	1 hour	Guinea pig	Increase in airway resistance; Increase in tidal volume; Decrease in respiratory rate	Murphy et al. (1964)[d]
10.0	5 hours	Rat	Decrease in respiratory rate	Lee et al. (1984)
10.0 - 20.0	Occupational	Human	Breathing difficulties; Cough	Zenz, ed. (1980)[g]
15.8 - 16.7	10 hour exposure to aerosol or vapor	Mouse, guinea pig, rabbit	Edema of lungs; Hemorrhage of lungs; Death in 20 to 90 percent of animals	Salem and Cullumbine (1960)[d,h]
49.0, 50.0	1 hour, 4 hours	Guinea pig	Increased airway resistance; Decreased compliance	Amdur (1959),[d] (1960)[d]
41.67	1 hour/day, 3 days/week, 35 weeks	Mouse	Bronchopneumonia	Horton et al. (1963)[c]
731	2 hours	Mouse	Massive pulmonary edema and hemorrhage	Horton et al. (1963)[d]
6,000	1 hour	Guinea pig	Increased airway resistance; Decreased respiration rate; No change in compliance	Davis et al. (1967)[d]
2,200-2,400 mg	Ingestion	Human	Cyanosis; Shallow respiration	Earp (1916)[d]

See footnotes at end of page. (continued)

TABLE 2-3 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
3.7% - 9.25% formaldehyde in aqueous solution	Occupational - renal hemodialysis nurses	Human	Asthma or bronchitis in 8 of 28 subjects; Positive bronchial provocation in 2 of 28 subjects; Asthma on challenge in 1 of 2 of the same subjects 6 years later	Hendrick and Lane (1975),[b,e,g] (1977),[b,e,g] (1982)
Formaldehyde in aqueous solution	Ingestion, 1½ oz	Human	Cyanosis; Shallow respiration	Earp (1916)[d]
1.8 - 3.3 μm	Solid and liquid aerosol	Mouse	Increased incidence of pulmonary edema	LaBelle et al. (1955)[b]
?	Inhalation of high concentration gas	Human	Pulmonary edema; Asthma in one subject	Zannini and Russo (1957)[d]
?	Inhalation of high concentration gas	Human	Pulmonary edema	Böhmer (1934)[d]
?	Occupational - physician	Human	Acute respiratory distress	Porter (1975)[a,b,d,e]
?	Occupational - hospital lab technician	Human	Acute respiratory distress	Sakula (1975)[a,b]

See footnotes at end of table. (continued)

TABLE 2-3 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
?	Occupational - embalmers	Human	Acute bronchitis in 9 of 57 subjects; Chronic bronchitis in 17 of 57 subjects	Plunkett and Barbella (1977)[a]
?	Occupational - workers using histiological fixatives	Human	Inflammatory changes in bronchial tract	Trinkler (1968)[b]
?	Occupational - clothes ironers	Human	Chronic bronchitis	Kratochvil (1971)[b]
?	Occupational - match factory workers	Human	Asthma	Vaughn (1939)[b]
?	Occupational - meatwrappers	Human	Asthma; Wheezing; Cough	Skerfving et al. (1980)[b]
?	Occupational	Human	Asthma	Popa et al. (1969)[b]
?	Residential	Human	Lung problems	Sardinas et al. (1979)
?	Residential	Human	Asthma in 5 of 1,396 subjects (nonsignificant); Wheezing in 8 of 1,396 subjects (significant); Chest pain in 11 of 1,396 subjects (nonsignificant); Cough in 30 of 1,396 subjects (nonsignificant)	Thun et al. (1982)

See footnotes at end of table. (continued)

TABLE 2-3 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
?	Residential	Human	Difficult breathing in 71 of 256 subjects; Wheezing in 50 of 256 subjects; Breathlessness in 44 of 256 subjects; Chest pain in 30 of 256 subjects; Bronchitis in 22 of 256 subjects; Pneumonia in 13 of 256 subjects; Chest tightness in 44 of 256 subjects	Dally et al. (1981)

[a]Cited in Federal Panel on Formaldehyde, 1982. "Report of the Federal Panel on Formaldehyde." Environmental Health Perspectives 43:139-168.

[b]Cited in Bardana, Emil J., 1980. Formaldehyde: Hypersensitivity and Irritant Reactions at Work and in the Home." Immunology and Allergy Practice II(3):11-23.

[c]Cited in Gupta, K. C., A. G. Ulsamer, and P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Source and Toxicity." Environment International 8:349-358.

[d]Cited in National Institute of Occupational Safety and Health, 1976. Criteria for a Recommended Standard . . . Occupational Exposure to Formaldehyde. DHEW (NIOSH) Publication No. 77-126. Washington, D. C.: Department of Health, Education, and Welfare.

[e]Cited in National Research Council, 1981. Formaldehyde and Other Aldehydes. Washington, D. C.

[f]Cited in Cosmetic Ingredient Review, 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology 3(3):157-184.

[g]Cited in Wartew, G. A., 1983. "The Health Hazards of Formaldehyde." Journal of Applied Toxicology 3(3):121-126.

[h]Cited in Loomis, T. A., 1979. "Formaldehyde Toxicity." Archives of Pathological Laboratory Medicine 103:321-324.

Low to moderate concentrations of formaldehyde (0.05 ppm to 0.3 ppm) are associated with the more minor effects such as cough, chest tightness, shortness of breath, and wheezing (Gamble et al., 1976; Kerfoot and Mooney, 1975; Hogan and Main, 1983; Shipkovitz, 1968). These effects are among the more severe experienced by those in a residential setting, where exposure concentrations are somewhat lower than for occupational settings (Thun et al., 1982; Sardinas et al., 1979; Dally et al., 1981). The National Research Council (1981) concluded that these effects are reported often by persons exposed to concentrations at 5.0 ppm to 30.0 ppm.

Some evidence to tolerance to these lower levels of exposure exists (Sim and Pattle, 1957). The tolerance develops after 10 to 15 minutes of exposure, but irritation returns after a 1- to 2-hour interruption of the exposure (Kerfoot and Mooney, 1975; Shipkovitz, 1968; Blejer and Miller, 1966).

Higher concentrations (above 0.33 ppm) cause decreases in pulmonary function, reduced expiratory volume, and increases in airway resistance (Amdur, 1959; Alexandersson et al., 1982; Kane and Alarie, 1977; Amdur, 1960; Murphy et al., 1964; Lee et al., 1984; Zenz, 1980; Davis et al., 1967). Gamble et al. (1976) noted decreased pulmonary function at 0.05 ppm in resin workers, but attributed the change to number of respirable particles inhaled, rather than to formaldehyde concentration.

Inflammation of the lungs has been observed in rats, dogs, rabbits, monkeys, and guinea pigs at concentrations from 3.83 ppm to 5.0 ppm (Coon et al., 1970). Inflammatory changes in the bronchial tract have been noted in humans occupationally exposed through the use of histiological fixatives (Trinkler, 1968).

Inactivation of the bronchial tree cilia was observed in rats at an exposure concentration of 3.5 ppm (Murphy et al., 1964). Edema and hemorrhage of the lungs occurs at 15.8 ppm to 16.7 ppm and above in the mouse, guinea pig, and rabbit (Salem and Cullumbine, 1960; Horton et al., 1963; LaBelle, 1955).

These symptoms have been noted in humans after inhalation of a high concentration of formaldehyde in gaseous form (Zannini and Russo, 1957; Bohmer, 1975). Acute respiratory distress has been reported in case studies

(Sakula, 1975; Porter, 1975). Ingestion of formaldehyde solution causes shallow breathing and cyanosis (Earp, 1916). The National Research Council (1981) concluded that formaldehyde levels from 50.0 ppm to 100.0 ppm can cause pulmonary edema, pneumonitis, with death expected to result at the upper end of the range.

It has been suspected that formaldehyde exposure results in sensitization through the inhalation pathway. Asthma and bronchitis symptoms have been observed in several occupational settings (Hendrick and Lane, 1975, 1977; Vaughn, 1939; Skerfving et al., 1980; Popa et al., 1969; Kratochvil, 1971; Plunkett and Barbella, 1977; Kerfoot and Mooney, 1975). Sensitization has been elicted in guinea pigs and rats at 1.67 ppm (Ostapovich, 1975) and in mice at 3.1 ppm induction and 0.55 ppm to 13.4 ppm challenge (Kane and Alarie, 1977).

Studies have failed to demonstrate conclusively that pulonary sensitization to formaldehyde in humans does occur (Lee et al., 1984; Gamble et al., 1976; Hendrick et al., 1982; Levine et al., 1984; Hogan and Main, 1983; Frigas et al., 1984).

2.3.4 <u>Skin Effects</u>

Reported effects of formaldehyde exposure on the skin are outlined in Table 2-4. Both primary irritant and allergic sensitization effects are possible. The contact and inhalation pathways are utilized in these reactions. Itching, burning, redness, rashes, and inflammation are irritation effects, while dermititis, eczema, and urticaria represent sensitization responses.

Even low concentrations of formaldehyde (0.01 percent to 0.0925 percent) in solution have been found to cause irritant effects in humans, rabbits, and guinea pigs (Fielder, 1981; Pirila and Kilpio, 1949; DuPont, 1970; Cosmetic, Toiletry, and Fragrance Association, 1975, 1976a, 1976b, 1977, 1978b, 1981).

Skin irritation has been reported in both occupational and residential exposures. A study of embalmers found that 37 percent of 57 subjects experienced irritation (Plunkett and Barbella, 1977). Permanent press fabric workers have reported redness and tightness of the skin (Kachlik,

TABLE 2-4. REPORTED SKIN EFFECTS OF FORMALDEHYDE EXPOSURE

Formaldehyde concentration (percent formal-dehyde in aqueous solution)	Length/type of exposure	Species	Effect	Reference
0.01	Occlusive patch	Human	Reaction in 1 of 5 formaldehyde sensitized subjects	Marzulli and Maibach (1973)[a]
0.01 - 0.02 (saline solution)	Patch	Guinea pig	Mild to moderate irritation	DuPont (1970)[b]
0.0185	Repeat insult patch	Human	Reaction in 4 of 101 subjects during induction; No reaction upon challenge	Cosmetic, Toiletry and Fragrance Association (CTFA) (1978a)[b]
0.02	Product exposure - newsprint	Human	Allergic dermititus reaction in formaldehyde-sensitized individual	Black (1971)[c]
0.03	Product exposure - paper towels	Human	Allergic dermititis reaction in formaldehyde-sensitized individual	Black (1971)[c]
0.037	Repeat insult patch	Human	Reaction in 6 of 200 subjects during induction; No reaction upon challenge	Industrial Biology Laboratories (1967)[b]
0.04	?	Guinea pig	Sensitization	Fielder (1981)[b]
0.074	Occlusive patch	Rabbit	Slight irritation	CTFA (1981)[b]
0.074	24 hour occlusive patch	Human	Slight erythmic response in 1 of 20 subjects	CFTA (1977)[b]

See footnotes at end of table. (continued)

TABLE 2-4 (continued)

Formaldehyde concentration (percent formaldehyde in aqueous solution)	Length/type of exposure	Species	Effect	Reference
0.074	21 daily applications under occlusive patch	Human	Irritation in 3 of 8 subjects	CFTA (1976a)[b]
0.074	24 hour occlusive patch	Human	Mild erythmic response in 1 of 19 subjects	CFTA (1975)[b]
0.074	Repeat insult patch	Human	Reaction in 4 of 204 subjects during induction; Reaction in 2 of 204 subjects upon challenge	CFTA (1976b)[b]
0.09 - 0.4	Occupational - glue workers	Human	Irritant dermititis in 14 subjects; Sensitization in 1 subject	Pirila and Kilpio (1949)[d]
0.0925	Occlusive patch	Rabbit	Slight irritation	CFTA (1981)[b]
0.0925	24 hour occlusive patch	Human	Slight erythmic response in 1 of 20 subjects	CFTA (1978b)[b]
0.1	Product exposure - cosmetics/toiletries containing Quaternium-15	Human	Sensitization	National Research Council (1981); Jordan et al. (1979)[b]
0.1, 0.2	Occlusive patch	Human	Reaction in 1 of 5 formaldehyde-sensitized subjects	Marzulli and Maibach (1973)[a]
0.1 - 20.0	Topical application	Rabbit	Mild to moderate irritation	DuPont (unpublished)[a]

See footnotes at end of table. (continued)

TABLE 2-4 (continued)

Formaldehyde concentration (percent formaldehyde in aqueous solution)	Length/type of exposure	Species	Effect	Reference
0.5	Occlusive patch	Human	Reaction in 2 of 5 formaldehyde-sensitized subjects	Marzulli and Maibach (1973)[a]
0.5	Occupational	Human	Fingernails become brown, soften, decay or become scaly and friable; Inflammation of skin folds of fingers	Chajes (1930)[d]
0.80	Occlusive patch	Human	Reaction in 4 percent of 1,200 subjects	North American Contact Dermititis Group (1973)[a]
1.0	Occlusive patch	Human	Reaction in 4 of 5 formaldehyde-sensitized subjects	Marzulli and Maibach (1973)[a]
1.0	Occupational - hairdressers using wave solution	Human	Primary irritant dermititis	Pirila and Kilpio (1949)[d]
1.0, 2.0	Open test	Human	Urticaria in one subject previously sensitized	Lindskov (1982)
2.0 (saline solution)	Topical application	Guinea pig	Contact sensitivity	Lee et al. (1984)
2.0	?	Guinea pig	Sensitization	Magnusson and Kligman (1977)[b]

See footnotes at end of table. (continued)

TABLE 2-4 (continued)

Formaldehyde concentration (percent formal- dehyde in aqueous solution)	Length/type of exposure	Species	Effect	Reference
2.0 (induction), 0.8 (challenge)	?	Guinea pig	Sensitization	CFTA (1981)[b]
2.0	?	Human	Sensitization in 124 of 2,374 subjects	North American Contact Dermititis Group (1980)[b]
2.0	Occupational - hemodialysis operators	Human	Dermititis in 6 of 13 subjects; Sensitization with 3% formalin solution in patch test	Sneddon (1968)[a,d]
2.0 - 10.0	Occupational	Human	Eczema on fingers; Vesicles, fissures ulcerations on hands extending to other parts of the body	Chajes (1930)[d]
4.0	Patch	Human	Allergic reaction in 137 of 2110 subjects; Formaldehyde eczema in 69 of the 137 who reacted	Hovding (1961)
5.0,10.0,20.0	?	Guinea	Mild to moderate irritation	DuPont (1970)[b]
10.0	Occupational - nurses handling thermometers immersed in formaldehyde solution	Human	Allergic contact dermititis; Sensitization responses in 5 subjects with patch tests from 0.5 to 5.0 percent formaldehyde	Rostenberg (1952)[a,d]
37.0	?	Guinea pig	Sensitization	Magnusson and Kligman (1977)[b]

See footnotes at end of table (continued)

TABLE 2-4 (continued)

Formaldehyde concentration (percent formal- dehyde in aqueous solution)	Length/type of exposure	Species	Effect	Reference
37.0 (with Freund's complete adjuvant)	Injection	Guinea pig	Sensitization	Lee et al. (1984)
0.05 ppm	Occupational - rubber workers	Human	Itch; Rash	Gamble et al. (1976)[e]
0.09-5.26 ppm	Occupational - embalmers	Human	Dermititis in 2 of 7 subjects	Kerfoot and Mooney (1975)[e]
4.0 ppm	?	Human	Irritation; Reddening and drying of skin	Commercial Solvents Corporation (unpublished)[d]
10-30 ppm (gaseous)	Occupational	Human	Eczema in formaldehyde-sensitized subjects	Harris (1953)[a,d]
16.0-30.0 ppm	Occupational	Human	Generalized skin reaction	Glass (1961)[d]
28.86 ppm (methanol and water solution)	Pump spray application, 2 times/day, two weeks	Human	Minimal dermititis in 2 of 13 subjects; Burning and itch in 3 of 13 subjects	Jordan et al. (1979)[b]
30 ppm (aqueous solution)	Closed patch, 168 hour reading	Human	Reaction in 4 of 9 formaldehyde-sensitized subjects	Jordan et al. (1979)[b]
60 ppm (aqueous solution)	Closed patch, 168 hour reading	Human	Reaction in 5 of 9 formaldehyde-sensitized subjects	Jordan et al. (1979)[b]

See footnotes at end of table. (continued)

TABLE 2-4 (continued)

Formaldehyde concentration (percent formaldehyde in aqueous solution)	Length/type of exposure	Species	Effect	Reference
100 ppm (aqueous solution)	Closed patch, 168 hour reading	Human	Reaction in 6 of 9 formaldehyde-sensitized subjects	Jordan et al. (1979)[b]
0.2 mg/L in water; 10.5ppm, 41.7 ppm	10 minutes immersion	Human	Dermatitis in sensitized subjects	Horsfall (1934)[d,f]
3.7g/L-37g/L (induction), 3.7 g/L (challenge)	Intermittent patch	Human	Sensitized in 4.5 percent to 7.8 percent of subjects	Marzulli and Maibach (1974)[f]
?	Occupational - grocer handling price labels	Human	Eczema in formaldehyde-sensitized individual	Pederson (1980)[g]
?	Occupational - embalmers	Human	Irritation in 37 percent in 57 subjects	Plunkett and Barbella (1977)[h]
?	Occupational - auto workers handling rubber	Human	Dermititis, 50 cases in 150 subject	Engel and Calnan (1966)[e]
?	Occupational - permanent press fabric workers	Human	Redness; Tightness; Acne in 63 cases	Kachlik (1968)[d]
?	Occupational - formaldehyde resin workers	Human	Dermititis occurring 3-6 weeks after exposure in 355 of 2,370 employees	Markuson et al. (1943)[d]

See footnotes at end of table. (continued)

TABLE 2-4 (continued)

Formaldehyde concentration (percent formal-dehyde in aqueous solution)	Length/type of exposure	Species	Effect	Reference
?	Occupational - urea-formaldehyde resin workers	Human	Dermititis, 26 cases in 300 subjects	Schwartz (1936)[d]
?	Occupational - phenol formaldehyde resin workers	Human	Dermititis, 27 cases in 400 subjects	Schwartz (1936)[d]
?	Occupational - plywood laminators	Human	Dermititis, 600 cases in 800 subjects	Schwartz et al. (1943)[e]
?	Occupational - tool makers handling plastics	Human	Dermititis in 40 of 100 subjects	Schwartz et al. (1943)[e]
?	Occupational - formaldehyde resin production workers	Human	Dermititis in 3 subjects	Rycroft (1982)
?	Residential	Human	Burning in 10 of 1,396 subjects (significant); Rash in 9 of 1,396 (nonsignificant)	Thun et al. (1982)
?	Residential	Human	Rash in 41 of 256 subjects	Dally et al. (1981)
?	Product exposure - orthopedic cast	Human	Contact dermititis in 3 subjects in 1972; Symptoms in 6 subjects in 1973	Logan and Perry (1972),[c] (1973)[d]

See footnotes at end of table. (continued)

TABLE 2-4 (continued)

Formaldehyde concentration (percent formaldehyde in aqueous solution)	Length/type of exposure	Species	Effect	Reference
?	Product exposure - nail hardener	Human	Reddening scaling of distal phalanges of one subject; Sensitization reaction with patch test of 5.0 percent formaldehyde in aqueous solution	Lazar (1966)[d]
?	Product exposure - permanent press clothing	Human	Eczema in sensitized subjects	Skogh (1959)[d]; Shellow and Altman (1966)[d]; O'Quinn and Kennedy (1965)[d]

[a]Cited in National Research Council, 1981. Formaldehyde and Other Aldehydes. Washington, D. C.

[b]Cited in Cosmetic Ingredient Review, 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology 3(3):157-184.

[c]Cited in Bardana, Emil J., 1980. Formaldehyde: Hypersensitivity and Irritant Reactions at Work and in the Home." Immunology and Allergy Practice II(3):11-23.

[d]Cited in National Institute of Occupational Safety and Health, 1976. Criteria for a Recommended Standard . . . Occupational Exposure to Formaldehyde. DHEW (NIOSH) Publication No. 77-126. Washington, D. C.: Department of Health, Education, and Welfare.

[e]Cited in Federal Panel on Formaldehyde, 1982. "Report of the Federal Panel on Formaldehyde." Environmental Health Perspectives 43:139-168.

[f]Cited in Gupta, K. C., A. G. Ulsamer, P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Sources and Toxicity." Environment International 8:349-358.

[g]Cited in Wartew, G. A., 1983. "The Health Hazards of Formaldehyde." Journal of Applied Toxicology 3(3):121-126.

[h]Cited in Loomis, T. A., 1979. "Formaldehyde Toxicity." Archives of Pathological Laboratory Medicine 103:321-324.

1968). Rash and burning of the skin have been reported due to residential exposure (Thun et al., 1981; Dally et al., 1981).

Exposure to products as diverse as newsprint, paper towels, toiletries, nail hardeners, orthopedic casts, and permanent press clothing which contain formaldehyde have elicited allergic reactions in sensitized subjects (Skogh, 1959; Shellow and Altman, 1966; O'Quinn and Kennedy, 1965; Lazar, 1966; Logan and Perry, 1972, 1973; Black, 1971; Jordan et al., 1979). Testing by the cosmetic industry has led to the conclusion by the Cosmetic Ingredient Review (1984) that safe use of formaldehyde above 0.2 percent in cosmetics has not been established.

Sensitization has two aspects. One is the elicitation of the initial reaction, that is, the exposure at which the sensitization actually occurs. The other is the elicitation of a reaction in an individual who has been previously sensitized. As mentioned in Section 2.2.2, the reaction of a sensitized individual usually occurs at lower concentrations of formaldehyde than the amount required to cause the reaction in the first place.

The onset of skin sensitization has been established for humans at low concentrations (0.074 percent formaldehyde in solution) (Cosmetic, Toiletry, and Fragrance Association, 1976b). Larger proportions of sensitized individuals react with increasing concentrations of formaldehyde (Marzulli and Maibach, 1973; North American Contact Dermititis Group, 1973, 1980; Hovding, 1961; Jordan et al., 1979). This result provides some evidence of an increasing dose-response function for skin sensitization.

A lower threshold for induction of repetitive nonimmunologic contact urticaria has been established at about one percent formaldehyde in solution (Marzulli and Maibach, 1974). A lower threshold for induction of allergic contact dermititis has been imprecisely determined at about five percent formaldehyde in solution, or 30 ppm formaldehyde (Jordan et al., 1979). No threshold has yet been established for immunologic contact urticaria (Consensus Workshop on Formaldehyde, 1983).

The elicitation of reactions in formaldehyde-sensitized individuals has occurred at concentrations as low as 0.01 percent formaldehyde in solution (Marzulli and Maibach, 1973). At higher levels less time is required for elicitation of response in sensitized individuals. Horsfall (1934) found that at 10.5 ppm reactions occurred in 10 minutes.

The implications are important for those occupationally exposed because these persons undergo a relatively high constant 8-hour exposure almost daily for many years of their lifetime. Since many previously "normal" persons develop sensitivity to formaldehyde, it is not unreasonable to expect that a number of individuals exposed in this setting will develop sensitivity (NRC, 1981). Once this sensitization is established, employment in occupations with extensive exposure for the individual may become impossible.

Reaction symptoms in sensitized individuals have been reported for many occupations including embalmers, grocers, auto workers, permanent press fabric workers, formaldehyde resin workers, plywood laminators, toolmakers, hemodialysis operators, nurses, hairdressers, glue workers, and rubber workers (Pirila and Kilpio, 1949; Rostenberg, 1952; Gamble et al., 1976; Kerfoot and Mooney, 1975; Glass, 1961; Pederson, 1980; Engel and Calnan, 1966; Markuson et al., 1943, Schwartz et al., 1936; Sneddon, 1968; Rycroft, 1982; Harris, 1953).

2.3.5 Gastrointestinal System Effects

Table 2-5 lists reported effects of formaldehyde on the gastrointestinal system. Minor effects such as vomiting, nausea, stomach cramps, and diarrhea may result from prolonged inhalation of formaldehyde. More serious effects such as severe gastrointestinal pain, dysphagia, and systemic damage derive from ingestion of formaldehyde.

Residential exposures by the inhalation pathway in the range of 0.02 ppm to 4.17 ppm are reported to cause vomiting, nausea, and diarrhea (Woodbury, 1979; Breysse, 1977; Sardinas et al., 1979; Garrey et al., 1980; Harris et al., 1981). Thun et al. (1982) reported the vomiting symptom, but indicated it was not statistically significant for the exposed group. Dally et al. (1981) reported nausea in 79 of 256 subjects and vomiting in 53 subjects.

More serious symptoms have occurred in rats from concentrations at 0.83 ppm in continuous exposure. These symptoms include decreased liver weight and increased epithelial proliferation of the common bile duct (Miaskiewicz et al., 1977; Gofmekler et al., 1968).

TABLE 2-5. REPORTED GASTROINTESTINAL SYSTEM EFFECTS OF FORMALDEHYDE EXPOSURE

Formaldehyde concentration	Length/type of exposure	Species	Effect	Reference
0.02 - 4.17 ppm	Residential	Human	Diarrhea; Nausea; Vomiting	Woodbury (1979);[a] Breysse (1977);[a] Sardinas et al. (1979);[a] Garry et al. (1980);[a] Harris et al. (1981)[a]
0.83 ppm	10 months over 2 generations	Rat	Decreased liver weight	Miaskiewicz et al. (1977)[a]
0.83 ppm	Continuous beginning 10 - 15 days before mating	Rat	Increased epithelial proliferation of common bile duct; Increased abnormalities of renal epithelium	Gofmekler et al. (1968)[a]
22 - 200 mg	Daily ingestion, 14 days	Human	Mild gastric discomfort	Yonkman et al. (1941)[b]
50, 100, 150 mg/kg	Daily ingestion in drinking water	Rat	Decreased weight gain	Monsanto (1973a)[c]
50, 75, 150 mg/kg	Daily ingestion in food	Dog	Decreased weight gain	Monsanto (1973b)[c]
100 - 200 mg	Daily ingestion in milk, 3 weeks	Human	Stomach pain	Wiley (1908)[b]

See footnotes at end of table. (continued)

TABLE 2-5 (continued)

Formaldehyde concentration	Length/type of exposure	Species	Effect	Reference
Varying concentrations	Ingestion, 0 - 7.5 oz	Human	Gastrointestinal pain; Corrosion of contact organs	Kline (1925)[b]
Formaldehyde in solution	Ingestion, 100 cc	Human	Severe epigastric pain; Dysphagia, stenosis, and corrosive destruction of stomach	Heffernon and Hajjar (1964)[b]
10% formaldehyde solution	Ingestion, 120 mL	Human	Dysphagia; Gastric shrinkage after 3 months	Bartone et al. (1968)[b]
30% formaldehyde solution	Ingestion	Human	Death	Böhmer (1934)[b]
37% formaldehyde solution	Ingestion, 240 mL	Human	Severe pain; Ulceration and stenosis of stomach	Roy et al. (1962)[b]
37% - 40% formaldehyde solution	Ingestion, ½ oz	Human	Dry and sore throat; Vomiting	Bower (1909)[b]
40% formaldehyde solution	Ingestion, 150 cc	Human	Death; Edema of glottis	Rathery et al. (1940)[b]
40% formaldehyde solution	Ingestion	Human	Death in child	Ely (1910)[b]

See footnotes at end of table. (continued)

TABLE 2-5 (continued)

Formaldehyde concentration	Length/type of exposure	Species	Effect	Reference
?	Residential	Human	Vomiting in 1 of 1,396 subjects (nonsignificant)	Thun et al. (1982)
?	Residential	Human	Nausea in 79 of 256 subjects; Vomiting in 53 of 245 subjects	Dally et al. (1981)
?	Ingestion	Human	Mucous membranes of mouth and throat turn dry and white; Vomiting	Earp (1916)[b]
?	Ingestion	Human	Immediate inflammation of linings of mouth, throat, and gastrointestinal tract	Zenz, ed. (1980)[d]

[a]Cited in Gupta, K. C., A. G. Ulsamer, P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Sources and Toxicity." Environment International 8:349-358.

[b]Cited in National Institute of Occupational Safety and Health, 1976. Criteria for a Recommended Standard . . . Occupational Exposure to Formaldehyde. DHEW (NIOSH) Publication No. 77-126. Washington, D. C.: Department of Health, Education, and Welfare.

[c]Cited in Cosmetic Ingredient Review, 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology 3(3):157-184.

[d]Cited in Wartew, G. A., 1983. "The Health Hazards of Formaldehyde." Journal of Applied Toxicology 3(3):121-126.

Mild symptoms from ingestion of formaldehyde involve very low doses. Dryness, whiteness, and inflammation of the mouth and throat and vomiting have been reported in humans following ingestion of 0.5 oz to 1.5 oz of formalin (Bower, 1909; Earp, 1916; Zenz, 1908).

Decreased weight gain in rats and dogs has been reported from ingestion of 150 mg/kg in drinking water daily and 100 mg/kg in food daily, respectively (Monsanto, 1973a, 1973b). Daily ingestion of 100 mg to 200 mg in milk over a 3-week period was found to cause stomach pain in humans (Wiley, 1908). Daily ingestion of 22 mg to 200 mg of formaldehyde over a 2-week period caused mild gastric discomfort in human subjects (Yonkman et al., 1941).

Severe epigastric pain, dysphagia, corrosion of contact organs, edema of glottis, ulceration and stenosis of the stomach, gastric shrinkage, and death have followed ingestion of small amounts (a few drops to 240 mL) of varying concentrations (10 percent to 40 percent formaldehyde in solution) of formaldehyde (Kline, 1925; Heffernon and Hajjar, 1964; Rathery et al., 1940; Roy et al., 1962; Bartone et al., 1968; Bohmer, 1934; Ely, 1910).

2.3.6 Central Nervous System Effects

Table 2-6 outlines reported central nervous system effects due to formaldehyde exposure. Headaches, fatigue, insomnia, and dizziness have been reported as symptomatic of low exposures from 0.02 ppm and above, in both the residential and occupational environments (Woodbury, 1979; Breysse, 1977; Sardinas et al., 1979; Garry et al., 1980; Harris et al., 1981; Kerfoot and Mooney, 1975; Hogan and Main, 1983; Bourne and Seferian, 1959; Thun et al., 1982; Dally et al., 1981).

Several studies have attempted to measure responses of the central nervous system to formaldehyde exposure utilizing physiological changes. Melekina (1964) determined thresholds for optional chronaxy at 0.07 ppm and for effects on the functional state of the cerebral cortex at 0.08 ppm. At 1.7 ppm, Melekhina (1964) observed eye sensitivity to light reduced for a dark-acclimated group.

Bonashevskaya (1973) found histological and histochemical changes in cerebral amygdaloid complex at 0.83 ppm. Alterations in functional state

TABLE 2-6. REPORTED CENTRAL NERVOUS SYSTEM EFFECTS OF FORMALDEHYDE EXPOSURE

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.02 - 4.27	Residential	Human	Headache	Woodbury (1979);[a] Breysse (1977);[a] Sardinas et al. (1979);[a] Garry et al. (1980);[a] Harris et al. (1981)[a]
0.07	Minutes	Human	Optical chronaxy threshold	Melekhina (1964)[a]
0.08	Minutes	Human	Threshold of effects on functional state of cerebral cortex	Melekhina (1964)[a]
0.08 - 5.58	Occupational	Human	Headaches	Kerfoot and Mooney (1975)[a]
0.12 - 1.25	Occupational chipboard makers	Human	Headaches; Fatigue	Hogan and Main (1983)
0.12 - 0.46	Occupational	Human	Headaches	Bourne and Seferian (1959)[a]
0.83	3 months	Rat	Histological and histochemical changes in cerebral amygdaloid complex	Bonashevskaya (1973)[a]
0.83	1 minute	Human	Altered functional state of cerebral cortex	Feldman and Bonashevskaya (1971)[a]
0.83	90 days	Rat	Focal hyperplasia and RE system activation in cerebral cortex	Feldman and Bonashevskaya (1971)[a]

See footnotes at end of table. (continued)

TABLE 2-6 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.83	10 minutes	Human	EEG changes; Alteration of autonomic nervous system	Sgibnev (1968)[a]
1.42	1 minute	Human	Eye sensitivity to light in unacclimated group	Melekhina (1964)[a]
4.17	4 hours/day	Rat	Increase in the threshold of neuromuscular excitability	Sheveleva (1971)[a]
?	Residential	Human	Headache in 16 of 1,396 subjects (nonsignificant); Insomnia in 11 of 1,396 subjects (nonsignificant); Dizziness in 5 of 1,396 subjects (nonsignificant)	Thun et al. (1981)
?	Residential	Human	Headache in 133 of 256 subjects; Difficulty sleeping in 97 of 256 subjects; Weakness in 56 of 256 subjects; Dizziness in 51 of 256 subjects	Dally et al. (1981)

[a]Cited in Gupta, K. C., A. G. Ulsamer, and P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Sources and Toxicity." Environment International 8:349-358.

of the cerebral cortex were observed by Feldman and Bonashevskaya (1971) at the same exposure. Sgibnev (1968) noted changes in electroencephalogram result, also at 0.83 ppm. An increase in the threshold of neuromuscular excitability in rats at 4.17 ppm was described by Sheveleva (1971).

2.3.7 Circulatory System Effects

The reported circulatory system effects due to formaldehyde exposure are outlined in Table 2-7. The effects listed result from inhalation and product contact.

Changes in blood chemistry of rats and guinea pigs were noted by Ostapovish (1975) and Sheveleva (1971) from exposures of 1.67 ppm and 4.17 ppm administered through the inhalation pathway. Symptoms included leucocytosis, changes in blood cholinesterase, decreased hemoglobin and an increase in peripheral white blood cells. Experiments by Stewart (1901) indicated that formaldehyde in solution may cause the loss of the ability of red blood cells to take up oxygen and the destruction of selective permeability in red blood cells.

Exposure of dialysis patients to dialyzers sterilized and contaminated with formaldehyde solutions leads to hemolysis, anemia, and peripheral blood eosinophia in some subjects (Fassbinder et al., 1979; Orringer and Mattern, 1976; Hoy and Cestero, 1979).

2.3.8 Reproductive System Effects

Table 2-8 outlines reported effects of formaldehyde exposure on the reproductive system.

Nagornyi et al. (1979) found a decrease in weight of testes of rats upon continuous exposure to 0.42 ppm formaldehyde over 6 months. However, the study failed to present histological data necessary to evaluate the pathological results.

Shumilina (1975) detected menstrual disorders and pregnancy complications in finishers and inspectors in a cotton mill at concentrations of 1.25 ppm to 3.83 ppm. However, stress and socioeconomic factors were not accounted for in the study.

Neshkov and Nosko (1976) reported complaints of male sexual dysfunction in 58 of 143 subjects studied in a plant producing glass-fiber reinforced

TABLE 2-7. REPORTED CIRCULATORY SYSTEM EFFECTS OF FORMALDEHYDE EXPOSURE

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
1.67	Continous or intermittent	Guinea pig	Leucocytosis; Change in blood cholinesterase	Ostapovich (1975)[a]
3.70	24 hours/day, 90 days	Guinea pig, rat	Chronic inflammatory changes in heart	Coon et al. (1970)[b]
4.17	4 hours/day	Rat	Increase in peripheral white blood cells; Decreased hemoglobin	Sheveleva (1971)[a]
0.2% (formaldehyde solution)	Treatment of cells	Human	Loss of ability of red blood cells to take up oxygen	Stewart (1901)[b]
4% (formaldehyde solution)	Treatment of cells	Human	Destruction of selective permeability in red blood cells	Stewart (1901)[b]
?	Product contact - dialyzers sterilized with formaldehyde	Human	Hemolysis leading to renally induced anemia in patients	Fassbinder et al. (1979)[c]
?	Product contact - dialyzers with dialysis water contaminated with formaldehyde	Human	Hemolytic anemia	Orringer and Mattern (1976)[d]

See footnotes at end of table. (continued)

TABLE 2-7 (continued)

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
?	Product contact - Dialyzers sterilized with formaldehyde	Human	Peripheral blood eosinophia in patients	Hoy and Cestero (1979)[e]

[a]Cited in Gupta, K. C., A. G. Ulsamer, P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Sources and Toxicity." Environment International 8:349-358.

[b]Cited in National Institute of Occupational Safety and Health, 1976. Criteria for a Recommended Standard . . . Occupational Exposure to Formaldehyde. DHEW (NIOSH) Publication No. 77-126. Washington, D. C.: Department of Health, Education, and Welfare.

[c]Cited in National Research Council, 1981. Formaldehyde and Other Aldehydes. Washington, D. C.

[d]Cited in Cosmetic Ingredient Review, 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology 3(3):157-184.

[e]Cited in Bardana, Emil J., 1980. Formaldehyde: Hypersensitivity and Irritant Reactions at Work and in the Home." Immunology and Allergy Practice II(3):11-23.

TABLE 2-8. REPORTED REPRODUCTIVE SYSTEM EFFECTS OF FORMALDEHYDE EXPOSURE

Formaldehyde concentration (ppm)	Length/type of exposure	Species	Effect	Reference
0.42	6 months continuous	Rat	Decrease in weight of testes	Nagornyi et al. (1979)[a]
1.25 - 3.83	Occupational	Human	Menstrual disorders; Pregnancy complications	Shumilina (1975)[a,b,c]
?	Occupational - plastic production workers	Human	Male sexual dysfunction in 58 of 143 subjects	Neshkov and Nosko (1976)[c]

[a]Cited in Wartew, G. A., 1983. "The Health Hazards of Formaldehyde." Journal of Applied Toxicology 3(3):121-126.

[b]Cited in Gupta, K. C., A. G. Ulsamer, P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Sources and Toxicity." Environment International 8:349-358.

[c]Cited in Federal Panel on Formaldehyde, 1982. "Report of the Federal Panel on Formaldehyde." Environmental Health Perspectives 43:139-168.

plastic. The study failed to utilize control groups and could not isolate formaldehyde from among the several toxic substances in the work environment.

A study by Andeeva et al. (1980) of women employed in a plywood factory where formaldehyde concentrations were about 1.25 ppm to 2.0 ppm indicated that gynocological disorders were nonsignificant among 13,000 cases of unfitness for work. Garry et al. (1980) investigated miscarriage rates among women exposed to formaldehyde in a residential environment, but found no significant difference from unexposed women.

2.4. SPECIAL POPULATION GROUPS

The studies concerning the health effects of formaldehyde cited above are limited to a small portion of the general population. As mentioned above, controlled experimental studies typically enroll healthy young adults, usually white males, to study adverse health outcomes. Most epidemiologic studies in industrial populations focus on males of working age (18 to 65 years) who are heathly enough to hold employment outside of the home. Some studies include women, but the sample size is usually small. Symptom surveys of people nonoccupationally exposed to formaldehyde have included persons of all ages, both male and female, but the analysis of these studies has not been done in an age-sex-specific way. Therefore, while we know what the disease burden of this population is as a whole, we do not know if, for example, children are more susceptible than adults, or if females are at greater risk than males for the consequences of formaldehyde exposure.

As with other pollutants or environmental agents, different subgroups of the population may be differently affected by similar exposures to formaldehyde. Calabrese (1978) has shown that males and females have different levels of susceptibility to various environmental pollutants, as demonstrated by differing cellular responses in experimental research. We know that men and women, and specific age groups have differential risk of heart disease, cancer at particular sites, and respiratory diseases. Based on experiences with outdoor air pollution, of which formaldehyde is a component, one might speculate that certain population groups are at high risk of irritation, sensitization, and other outcomes of formaldehyde exposure. These groups include newborns and young children, the elderly, persons with preexisting respiratory diseases, and atopic individuals (persons with allergies) (Small, 1982). The special features of each of these groups which enhance their susceptibility to formaldehyde will be addressed in turn.

2.4.1 Newborns and Young Children

Newborns and young children have displayed irritation effects through the inhalation pathway (NRC, 1981). The Consensus Workshop on Formaldehyde (1983) attributed the potentially greater likelihood of symptomatic response in children to a faster breathing rate in the younger age group than in adults.

A survey conducted by the Wisconsin Division of Health and cited by the NRC (1981) indicated that nosebleeds and rashes were common in infants and young children exposed in the 96 homes studied with formaldehyde levels at 0.68 + 0.66 ppm. Nine of 23 infants were hospitalized with symptoms such as vomiting, diarrhea, and respiratory problems. The symptoms were reported to disappear after the infants were removed from the homes.

Like individuals in the general population, infants and young children have shown respiratory susceptibility to passive smoking (Surgeon General, 1984) and to use of gas cooking fuels, and coal and wood burning stoves (Florey et al., 1979). The heightened exposure can cause susceptibility to appear lower for this very young age group, even if tolerance is not actually lower than for adults. The result is the same as if it were lower, since the group will display effects that adults in the same environment may not.

Contact irritation for newborns and young children has not to our knowledge been documented. It is generally accepted that infants and young children have skin that is more sensitive to many chemicals than do adults. Formaldehyde may be such a chemical, since it is known to be irritating for adults. Many cosmetic products such as shampoo, lotion, oil, and powder formulated for babies contain from less than 0.1 percent to 1.0 percent formaldehyde. According to the Cosmetic Ingredient Review Expert Panel (1984), evidence is inadequate to certify as safe for adults cosmetic products containing more than 0.2 percent formaldehyde.

Sensitization effects in infants and young children are suspected for formaldehyde exposure. The Consensus Workshop on Formaldehyde (1983) noted that studies have implicated formaldehyde as a potential factor predisposing children to respiratory tract infections. Formaldehyde is also a suspected contributing factor to Sudden Infant Death Syndrome (SIDS) at levels possibly found in mobile homes (Small, 1982). Further studies are recommended and are actually underway in the case of SIDS (Small, 1982).

2.4.2 The Elderly

Studies of formaldehyde-related symptoms in the elderly are few. One may speculate, however, that this group may have additional sensitivity to respiratory, gastrointestinal, or dermal irritation or other effects, because the body's immune system declines with advancing age. Other diseases show similar trends in incidence and prevalence in the elderly, and formaldehyde induced disease may also show this pattern (Small, 1982). The coexistence of other chronic diseases in the elderly may facilitate the expression of formaldehyde-related symptoms and disease.

2.4.3 Persons with Preexisting Respiratory Diseases

The compromise of the respiratory system in persons with preexisting disease may make them additionally susceptible to chemical insults. These persons have hyperreactive airways and may have a lower threshold dose of formaldehyde associated with the onset of symptoms (Small, 1982; Consensus Workshop on Formaldehyde, 1983; Gupta et al., 1982). The National Research Council (1981) indicated that such conditions are present in about 25 million persons (or about 10 to 12 percent of the population) in the United States.

Persons with asthma, chronic obstructive lung disease, chronic obstructive pulomonary disease, and some others who react positively to methacholine challenge tests are candidates for heightened sensitivity to formaldehyde (NRC, 1981). However, asthmatic controls used in a study by Hendrick et al. (1982) failed to respond to formaldehyde, even when subjected to exposures of 5 to 8 ppm for 60 minutes. A paucity of studies using asthmatics and others with respiratory conditions as primary subjects of the study precludes definite conclusions.

2.4.4 Atopic Persons

Persons who have allergic reactions to common allergens including inhalants and foods may also be more sensitive to formaldehyde than others (Small, 1982). Persons with allergies may react to exposures of lower concentration or shorter duration than nonatopic persons (Loomis, 1979).

Atopics may be more likely to experience allergic contact dermatitis or respiratory problems than the general population (Consensus Workshop on Formaldehyde, 1983). Although individual experiences suggest these results, the Consensus Workshop on Formaldehyde (1983) indicated it was unaware of controlled studies documenting presensitization effects of other chemicals.

2.5 REFERENCES

Alexandersson, R., B. Kolmodin-Hedman, and G. Hedenotierna, 1982. "Exposure to Formaldehyde: Effects on Pulmonary Function." Archives of Environ mental Health 37(5):279-284.

Amdur, M. O., 1959. "The Physiological Response of Guinea Pigs to Atmospheric Pollutants." International Journal of Air Pollution 1:170-183.

Amdur, M. O., 1960. "The Response of Guinea Pigs to Inhalation of Formaldehyde and Formic Acid Alone and With a Sodium Chloride Aerosol." International Journal of Air Pollution 3:201-220.

Andeeva, I. A., V. P. Agudin, L. M. Barysheva, B. I. Karpunin, and I. Ya. Saidasheva, 1980. "Physiological-Hygienic Evaluation of the Work of Women in Plywood Production." Gigiena Truda i Professional'nye Zabolevaniya [Russian] (2):30-32.

Anderson, I., 1979. "Formaldehyde in Indoor Environment-Health Implications and the Setting of Standards." In Fanger, P. O., and O. Valbjorn, ed. Indoor Climate: Effects on Human Comfort, Performance and Health in Residential, Commercial, and Light-Industry Buildings. Proceedings of the First International Indoor Climate Symposium, Copenhagen, August 30-September 1, 1978. Copenhagen: Danish Building Research Institute. pp. 65-87.

Andersen, K. E., N. Hyorth, H. Bundgaard, and M. Johansen, 1983. "Formaldehyde in a Hypoallergenic Non-woven Textile Acrylate Tape." Contact Dermititis 9(3):228.

Bardana, E. J., 1980. "Formaldehyde: Hypersensitivity and Irritant Reactions at Work and in the Home." Immunology and Allergy Practice II(3):11-23.

Barrow, C. S., W. H. Steinhagen, and J.C.F. Chang, 1983. "Formaldehyde Sensory Irritation." In Gibson, J. E., ed. Formaldehyde Toxicity. Washington, D.C.: Hemisphere Publishing Co. pp. 17-24.

Bender, J. R., L. S. Mullin, G. J. Graepel, and W. E. Wilson, 1983. "Eye Irritation Response of Humans to Formaldehyde." American Industrial Hygiene Association Journal 44(6):463-465.

Black, H., 1971. "Contact Dermititis from Formaldehyde in Newsprint." Contact Dermititis Newsletter 10:162.

Blejer, H. P., and B. H. Miller, 1966. Occupational Health Report of Formaldehyde Concentrations and Effects on Workers at the Bayly Manufacturing Company, Visalia, California. Study Report No. S-1806. Los Angeles: State of California Health and Welfare Agency, Department of Public Health.

Bohmer, K., 1934. "Formalin Poisoning." Deutsche Zeitschrift fuer die Gesamte Gerichtliche Medizin [German] 23:7-18.

Bourne, H. G., Jr., and S. Seferian, 1959. "Insufficiently Polymerized Resins Used for Wrinkle-Proofing Clothing May Liberate Toxic Quantities of Formaldehyde." Industrial Medicine and Surgery 28:232.

Breysse, P. A., 1977. "Formaldehyde in Mobile and Conventional Homes." Environmental Health Safety News 26:1-20.

Calabrese, E. J., 1978. Pollutants and High Risk Groups: The Biological Basis for Increased Susceptibility to Environmental and Occupational Pollutants. New York: Wiley Publishing Co.

Chajes, B., 1930. "Formaldehyde, Formalin." In Occupational and Health, Encyclopedia of Hygiene, Pathology and Social Welfare. Vol. I. International Labour Office. Geneva:Noirclerc et Fenetrier. pp. 806-810.

Commercial Solvents Corporation. Technical Data Sheet OC Series. TDS No. 5. Formaldehyde. New York. 4 pp.

Consensus Workshop on Formaldehyde, 1983. Deliberations of the Consensus Workshop on Formaldehyde. Proceedings of a workshop held October 3-6, 1983 in Little Rock, Arkansas.

Consumer Product Safety Commission (CPSC), 1982. "Consumer Product Safety Commission Ban of UFFI, Withdrawal of Proposed Information Labeling Rule, and Denial of Petition to Issue a Standard." Federal Register 47(64):14366-14419.

Coon, R. A., R. A. Jones, C. R. Jenkin, Jr., and J. Siegel, 1970. "Animal Inhalation Studies on Ammonia, Ethylene Glycol, Formaldehyde, Dimethylamine, and Ethanol." Toxicology and Applied Pharmacology 16:646-655.

Cosmetic Ingredient Review (CIR), 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology 3(3):157-184.

Cosmetic, Toiletry, and Fragrance Association (CTFA), 1975. Human Skin Irritation. CTFA Code 2-1-25. Skin Cleanser. Unpublished data.

Cosmetic, Toiletry, and Fragrance Association (CTFA), 1976a. Twenty-one Cumulative Irritancy Assay. CTFA Code 2-1-23. Facial Cleanser. Unpublished data.

Cosmetic, Toiletry, and Fragrance Association (CTFA), 1976b. Skin Allergy Testing. CTFA Code 2-1-24. Facial Cleanser. Unpublished data.

Cosmetic, Toiletry, and Fragrance Association (CTFA), 1977. Human Skin Irritation. CTFA Code 2-1-38. Skin Moisturizer. Unpublished data.

Cosmetic, Toiletry, and Fragrance Association (CTFA), 1978a. Allergic Contact Sensitization Test. Test No. APTC-045-78. CTFA Code 2-1-36. Hair care product. Unpublished data.

Cosmetic, Toiletry, and Fragrance Association (CTFA), 1978b. Human Skin Irritation. CTFA Code 2-1-38. Skin Moisturizer. Unpublished data.

Cosmetic, Toiletry, and Fragrance Association (CTFA), 1981. Formaldehyde: Cosmetic Ingredient Safety Analysis. Summary. Unpublished data.

Dally, K. A., L. P. Hanrahan, M. A. Woodbury, and M. S. Kanarek, 1981. "Formaldehyde Exposure in Non-occupational Environments." Archives of Environmental Health 36(6):277-284.

Davis, T. R. A., S. P. Battista, and C. J. Kensler, 1967. "Mechanism of Respiratory Effects During Exposure of Guinea Pigs to Irritants." Archives of Environmental Health 15:412-419.

Dorland's Illustrated Medical Dictionary, 1974. Philadelphia: W.B. Saunders Co.

DuPont de Nemours and Company, 1970. Primary Skin Irritation and Sensitization Test on Guinea Pigs. Haskell Laboratory for Toxicology and Industrial Medicine.

Earp, S. E., 1916. "The Physiological and Toxic Actions of Formaldehyde - With a Report of Three Cases of Poisoning by Formalin." New York Medical Journal 104:391-392.

Ely, F., 1910. "Formaldehyde Poisoning." Journal of the American Medical Association 54:1140-1141.

Engel, H. O., and C. D. Calnan, 1966. "Resin Dermititis in a Car Factory." British Journal of Industrial Medicine 23:62-66.

Environmental Protection Agency (EPA), 1984. "Formaldehyde; Determination of Significant Risk; Advance Notice of Proposed Rulemaking and Notice." Federal Register 49(101):21870-12898.

Fassbinder, W., U. Frei, and K. M. Koch, 1979. "Haemolysis Due to Formaldehyde-Induced Anti-N-Like Antibodies in Haemodialysis Patients." Klinishce Wochenschrift [German] 57:673-679.

Federal Panel on Formaldehyde, 1982. "Report of the Federal Panel on Formaldehyde." Environmental Health Perspectives 43:139-168.

Feldman, Y. U. G., and T. I. Bonashevskaya, 1971. "On the Effects of Low Concentrations of Formaldehyde." Gigiena i Sanitariya [Russian] 36(5):174-180.

Fielder, R. J., 1981. Toxicity Review 2--Formaldehyde. Her Majesty's Stationery Office, London. Publishers: Eyre and Spottiswoode, Grosvenor Press Portsmouth. Prepared for the Health and Safety Executive.

Finklea, J. F., D. I. Hammer, D. E. House, C. R. Sharp, W. C. Nelson, and G. R. Lowrimore, 1971. "Frequency of Acute Lower Respiratory Disease in Children: Retrospective Survey of Five Rocky Mountain Communities: 1967-1970. In U.S. Environmental Protection Agency. Health Consequences of Sulfur Oxides: A Report from CHESS, 1970-1971, Washington, D. C. pp. 3-35 - 3-56.

Florey, C. duV., R. J. W. Melia, S. Chinn, B. D. Goldstein, A. G. F. Brooks, H. H. John, I. B. Craighead, and X. Webster, 1979. "The Relationship Between Respiratory Illness in Primary Schoolchildren and the Use of Gas for Cooking. III Nitrogen Dioxide, Respiratory Illness and Lung Infection." International Journal of Epidemiology 8:347-353.

Freeman, H. G., and W. C. Grendon, 1971. "Formaldehyde Detection and Control in the Wood Industry. Forest Products Journal 21(9):54-57.

Frigas, E., W. V. Filley, and C. E. Reed, 1984. "Bronchial Challenge with Formaldehyde Gas: Lack of Bronchioconstriction in 13 Patients Suspected of Having Formaldehyde-Induced Asthma." Mayo Clinic Proceedings 59:295-299.

Gamble, J., 1983. "Effects of Formaldehyde on the Respiratory System." In Gibson, J. E., ed. Formaldehyde Toxicity. Washington, D.C.: Hemisphere Publishing Co.

Gamble, J. F., A. J. McMichael, T. Williams, and M. Battigelli, 1976. "Respiratory Function and Symptoms: An Environmental-Epidemiological Study of Rubber Workers Exposed to Phenol-Formaldehyde Type Resin." American Industrial Hygiene Association Journal 37:499-513.

Garry, V. F., L. Oatman, R. Pleuss, and D. Gray, 1980. "Formaldehyde in the Home - Some Environmental Disease Perspectives." Minnesota Medicine 63:107-111.

Glass, W. I., 1961. "An Outbreak of Formaldehyde Dermititis." New Zealand Medical Journal 60:423-427.

Gupta, K. C., A. G. Ulsamer, and P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Sources and Toxicity." Environmental International 8:349-358.

Harris, D. K., 1953. "Health Problems in the Manufacture and Use of Plastics. British Journal of Industrial Medicine 10:255-268.

Harris, J. C., B. H. Rumack, and F. D. Aldrick, 1981. "Toxicology of Urea-Formaldehyde and Polyurethane Foam Insulation." Journal of the American Medical Association 245:243-246.

Hendrick, D. J., and D. J. Lane, 1975. "Formalin Asthma in Hospital Staff." British Medical Journal. 1:607-608.

Hendrick, D. J., and D. J. Lane, 1977. "Occupational Formalin Asthma." British Journal of Industrial Medicine 34:11-18.

Hendrick, David J., Roy J. Rando, Donald J. Lane, and M. Joycelyn Morris, 1982. "Formaldehyde Asthma: Challenge Exposure and Fate After Five Years." Journal of Occupational Medicine 24(11):893-897.

Hogan, David M., and Theodore J. Main, 1983. "Health Effects of Low-Level Exposure to Formaldehyde." Journal of Occupational Medicine 25(2): 896-900.

Horsfall, F. L., 1934. "Formaldehyde Hypersensitiveness--An Experimental Study." Journal of Immunology 27:569-581.

Horton, A. W., R. Tye, and K. L. Stemmer, 1963. "Experimental Carcinogenesis of the Lung, Inhalation of Gaseous Formaldehyde or an Aerosol of Coal Tar by C_3H Mice." Journal of the National Cancer Institute 30:31-43.

Hovding, G., 1961. "Contact Eczema Due to Formaldehyde in Resin Finished Textiles." Acta Dermato-Venereologica 41:194-200.

Hoy, W. E., and R. V. M. Cestero, 1979. "Eosinophilia in Maintenance Hemodialysis Patients." Journal of Dialysis. 3:73.

Industrial Biology Laboratories, 1967. Repeated Insult Patch Test. CTFA Code 2-1-37. Facial Moisturizer. Unpublished data.

International Agency for Research on Cancer (IARC), 1982. Evaluation of the Carcinogenic Risk of Chemicals to Humans: Some Industrial Chemicals and Dyestuffs. Monograph. Vol. 29, pp. 345-389.

Jordan, W. P., W. T. Sherman, and S. E. King, 1979. "Threshold Response in Formaldehyde-Sensitive Subjects." Journal of the American Academy of Dermatology 1:44-48.

Kachlik, Z., 1968. "Mass Outbreak of Occupational Skin Disorders in Clothing Plant When Processing Materials with Crease-Resistant Finish. Pracovni Lekarstr [Czech] 20:154-158.

Kane, L. E., Y. Alarie, 1977. "Sensory Irritation to Formaldehyde and Acrolein During Single and Repeated Exposures in Mice." American Industrial Hygiene Association Journal 38:509-522.

Kerfoot, E. J., and T. F. Mooney, 1975. "Formaldehyde and Paraformaldehyde Study in Funeral Homes. American Industrial Hygiene Association Journal 36:533-537.

Kratochvil, I., 1971. "Health Hazards Caused by Formaldehyde Liberated from an Anti-Crease Textile Finish." Pracovni Lekarstr [Czech] 23:374.

LaBelle, C. W., J. E. Long, and E. E. Christofano, 1955. "Synergistic Effects of Aerosols." AMA Archives of Industrial Health 11:297.

Lazar, P., 1966. "Reactions to Nail Hardeners." Archives of Dermatology 92:446-448.

Lee, Hye Kyung, Yves Alarie, and Meryl H. Karol, 1984. "Induction of Formaldehyde Sensitivity in Guinea Pigs." Toxicology and Applied Pharmocology. 75:147-155.

Leonardos, G., D. Kendall, and N. Barnard, 1969. "Odor Threshold Determinations of 53 Deodorant Chemicals." Journal of the Air Pollution Control Assocation 19:91-95.

Levine, R. J., R. D. Dal Corso, P. B. Burnden, and M. C. Battigelli, 1984. "The Effects of Occupational Exposure on the Respiratory Health of West Virginia Morticians." Journal of Occupational Medicine 26(2): 91-98.

Lindskov, R., 1982. "Contact Urticaria to Formaldehyde." Contact Dermatitis 8(5):333-334.

Logan, N. S., and H. O. Perry, 1972. "Cast Dermatitis Due to Formaldehyde Sensitivity." Archives of Dermatology 106:717.

Logan, N. S., and H. O. Perry, 1973. "Contact Dermititis to Resin-Containing Casts." Clinical Orthopaedics 90:150-152.

Magnusson, B., and A. M. Kligman, 1977. "Usefulness of Guinea Pig Tests for Detection of Contact Sensitizers." In Marzulli, N., and H. I. Maibach, ed. Advances in Modern Toxicology, Vol. 4, Dermatotoxicology and Pharmacology. Washington, D.C.: Hemisphere Publishing Co. pp. 551-560.

Maibach, H., 1983. "Formaldehyde Effects on Animal and Human Skin." In Gibson, J. E., ed., Formaldehyde Toxicity Washington D.C.: Hemisphere Publishing Co. pp. 166-173.

Main, D. M., and T. J. Hogan,1983. "Health Effects of Low-level Exposure to Formaldehyde." Journal of Occupational Medicine 25(2):896-900.

Markuson, K. E., T. F. Mancuso, and J. S. Soet, 1943. "Dermititis Due to the Formaldehyde Resins--Prevention and Methods of Control." Industrial Medicine 12:383-386.

Marzulli, F. N., and H. I. Maibach, 1973. "Antimicrobials: Experimental Contact Sensitization in Man." Journal of the Society of Costmetic Chemists 24:399-421.

Marzulli, F. N., and H. I. Maibach, 1974. "The Use of Graded Concentrations in Studying Skin Sensitizers: Experimental Contact Sensitization in Man. Food and Cosmetics Toxicology 12:210-227.

Melekhina, V. P., 1964. "Hygienic Evaluation of Formaldehyde as an Atmospheric Air Pollutant." In Levine, B. S., ed. U.S.S.R. Literature on Air Pollution and Related Occupational Diseases. Vol. 9. A Survey. Washington, D.C.: U.S. Public Health Service. pp. 9-18.

Miller, B. H., and H. P. Blejer, 1966. Report of an Occupational Health Study of Formaldehyde Concentrations at Maximes, 400 E. Colorado Street, Pasadena, California. Study Report No. S-1838. Los Angeles: State of California Health and Welfare Agency, Department of Public Health.

Misiakiewicz, Z., G. Szulinska, A. Chyba, and E. Czyz, 1977. Effect of Formaldehyde on the Development of Rats During Long Term Continuous Exposure." Roczniki Panstwowego Zakladu Higieny [Polish] 28:99-106.

Monsanto Company, 1973a. "Ninety-day Rat Feeding Study on Formaldehyde." Project No. PRL 73-14. Performed by Pharmacopathics Research Laboratories. St. Louis, Missouri: Monsanto Co.

Monsanto Company, 1973b. "Ninety-day Dog Feeding Study on Formaldehyde." Project No. PRL 73-14. Performed by Pharmacophathics Research Laboratories. St. Louis, Missouri: Monsanto Co.

Most, R. S., G. R. Curry, A. V. Sardinas, and J. S. Marks, 1981. "Persistance of Symptoms Associated with Urea-formaldehyde Foam Insulation. Journal of Environmental Health 43:251-253.

Murphy, S. D., M. V. Davis, and V. L. Zaratizian, 1964. "Biochemical Effects in Rats from Irritating Air Contaminants." Toxicology and Applied Pharmacology 6:520.

Nagornyi, P. A., Zh. A. Sudakova, and S. M. Schablenko, 1979. "General Toxic and Allergic Effects of Formaldehyde." Giegiena Truda i Professional'nye Zabolevaniya [Russian] (1):27-30.

National Research Council (NRC), Committee on Aldehydes, 1981. Formaldehyde and Other Aldehydes. Washington, D.C.: National Academy Press.

Neshkov, N. S., and A. M. Nosko, 1976. "Effect of Toxic Components of Fiberglass-Reinforced Plastics on the Higher Nervous Activity and Sexual Function in Male Workers." Gigiena Truda i Professional'nye Zabolevaniya [Russian] 12:92-94.

North American Contact Dermititis Group, 1973. "Epidemiology of Contact Dermatitis in North America: 1972." Archives of Dermatology 108: 537-540.

North American Dermititis Group, 1980. Standard Screening Tray 1979 vs. 1980 Summary.

O'Quinn, S. E., and C. B. Kennedy, 1965. "Contact Dermititis Due to Formaldehyde in Clothing Textiles." Journal of the American Medical Association 194:593-596.

Orringer, E. P., and W. D. Mattern, 1976. "Formaldehyde-Induced Hemolysis During Chronic Hemodialysis." New England Journal of Medicine 294:1416-1420.

Ostapovich, I. K., 1975. "The Features of Sensitizing Action of Sulfurous Anhydride and Formaldehyde in Various Regimens of Their Inhalation." Gigiena i Sanitariya [Russian] 2:9-13.

Pederson, N. B., 1980. "Occupational Hand Eczema from Formaldehyde in Price Labels." Contact Dermatitis 6(1):57-58.

Pirila, V., and O. Kilpio, 1949. "On Dermititis Caused by Formaldehyde and Its Compounds." Annales Medicinae Internae Fenniae [Finnish] 38:38-51.

Plunkett, E. R., and T. Barbella, 1977. "Are Embalmers at Risk?" American Industrial Hygiene Association Journal 36:533-537.

Popa, V., D. Teculescu, D. Stanescu, and N. Garrilscu, 1969. "Bronchial Asthma and Asthmatic Bronchitis Determined by Simple Chemicals." Diseases of the Chest 65:395.

Porter, J. A. H., 1975, "Acute Respiratory Distress Following Formalin Inhalation." Lancet 1:603-604.

Rader, J., 1974. Irritant Effects of Formaldehyde in Anatomy Laboratories: Analytical and Experimental Investigations. Doctoral dissertation. University of Wurzburg.

Robbins, S. L., and M. Angell, 1976. Basic Pathology. Philadelphia: W. B. Saunders Co.

Rostenberg, A., Jr., B. Bairstow, and T. W. Luther, 1952. "A Study of Eczematous Sensitivity to Formaldehyde." Journal of Investigative Dermatology. 19:459-462.

Rycroft, R. J. G. 1982. "Contact Sensitization to 2-Monomethylol Phenol in Phenol Formaldehyde Resin as an Example of the Recognition and Prevention of Industrial Dermatoses." Clinical and Experimental Dermatology 7(3):285-290.

Sakula, A., 1975. "Formalin Asthma in Hospital Laboratory Staff." Lancet 2:816.

Salem, H., and H. Cullumbine, 1960. "Inhalation Toxicities of Some Aldehydes." Toxicology and Applied Pharmacology 2:183-187.

Sardinas, A. V., R. S. Most, M. A. Giulietti, and P. Honchar, 1979. "Health Effects Associated with Urea-Formaldehyde Foam Insulation in Connecticut." Journal of Environmental Health 41(5)270-272.

Schoenberg, J. B., and C. A. Mitchell, 1975. "Airway Disease Caused by Phenolic (Phenol-Formaldehyde) Resin Exposure." Archives of Environmental Health 30:574-577.

Schwartz, L., 1936. "Dermatitis in the Manufacture of Synthetic Resins and Waxes." In Skin Hazards in American Industry. Part II. Public Health Bulletin 229. U.S. Treasury Department. pp. 1-12.

Schwartz, L., S. M. Peck, and J. E. Dunn, 1943. "Dermititis from Resin Glue in War Industries." Public Health Report 58:899-904.

Sgibnev, A. K., 1968. "Effect of Formaldehyde Fume Concentrations on Humans." Gigiena Truda i Professional'nye Zabolevaniya [Russian] (12):20.

Shellow, H., and A. T. Altman, 1966. "Dermatitis from Formaldehyde Resin Textiles." Archives of Dermatology 94:799-801.

Sheveleva, G. A., 1971. "Investigation of the Specific Effect of Formaldehyde on the Embryogenesis and Progeny in White Rats." Toksikologiya Novykh Promyshlennykh Khimicheskikh Veshchestv [Russian] 12:78-86.

Shipkovitz, H. D., 1968. Formaldehyde Vapor Emissions in the Permanent Press Fabrics Industry. Report TR-52. Prepared for Public Health Service, Department of Health, Education, and Welfare. Cincinnati, Ohio.

Shumilina, A. V., 1971. "Menstrual and Reproductive Functions in Workers with Occupational Exposure to Formaldehyde." Gigiena Truda i Professional'nye Zabolevaniya [Russian] (12):18-21.

Skerfving, S., B. Akesson, B. G. Simonsson, 1980. "Meatwrappers' Asthma Caused by Thermal Degradation Products of Polyethylene." Lancet 1:211.

Skogh, M., 1959. "Axillary Eczema in Women, a Syndrome." Acta Dermato Venereologica 39:348-356.

Small, Bruce, 1982. The Susceptibility Report: Chemical Susceptibility and Urea-Formaldehyde Foam Insulation. Cornwall, Ontario: DECO-PLANS Inc.

Sneddon, I. B., 1968. "Dermatitis in an Intermittent Haemodialysis Unit." British Medical Journal 1:183-184.

Solomon, W. R., 1982. "Disturbances of Immune Mechanisms (Part 2)." In Price, S. A., and L. M. Wilson, ed. Pathophysiology, Clinical Concepts of Disease Processes. New York: McGraw-Hill Book Co. pp.

Stewart, G. N., 1901. "The Conditions that Underlie the Peculiarities in the Behaviour of the Coloured Blood-Corpuscles to Certain Substances." Journal of Physiology 26:470-496.

Surgeon General's Report, 1984. The Health Consequences of Smoking: Chronic Obstructive Lung Disease. Publication No. (PHS) 84-50205. Washington, D.C.: U.S. Department of Health and Human Services.

Thun, M. J., M. F. Lakat, and R. Altman, 1982. "Symptom Survey of Residents of Homes Insulated with Urea-formaldehyde Foam." Environmental Research 29:320-334.

Trinkler, H., 1968. "Working With Formaldehyde." Medizinsiche Laboratorium [German] 21:283.

Vaughn, W. T., 1939. The Practice of Allergy. St. Louis: C. V. Mosby.

Wahren, H., 1980. "Swedish Indoor Air Standards." Presentation at U.S. Consumer Product Safety Commission technical workshop on formaldehyde.

Walker, J. F., 1966. "Formaldehyde." In Kirk-Othmer Encyclopedia of Chemical Technology. Vol. 10. ed. 2 rev. New York: Interscience Publishers. pp. 77-99.

Wayne, L. G., R. J. Bryan, and K. Ziedman, 1977. Irritant Effects of Industrial Chemicals: Formaldehyde. DHEW (NIOSH) Publication No. 77-117. Cincinnati, Ohio: U.S. Department of Health, Education, and Welfare, National Institute of Occupational Safety and Health.

Williams, T. M., R. J. Levine, and P. B. Blunden, 1984. "Exposure of Embalmers to Formaldehyde and Other Chemicals." American Industrial Hygiene Association Journal 45(3):172-176.

Woodbury, M. A., and C. Zenz, 1978. "Formaldehyde Vapor Problems in Homes from Chipboard and Foam Insulation." Paper presented to the Wisconsin Department of Health, Education, and Welfare, Committee to Coordinate Toxicology and Related Programs.

Yefremov, G. G., 1970. "The State of the Upper Respiratory Tract in Formaldehyde Production Employees." Zhurnal Ushnykh Nosvykhi Gorlovykh Boleznei [Russian] 30:11-15.

Zaeva, G. N., I. P. Ulanova, and L. A. Dueva, 1968. "Materials for Revision of the Maximal Permissible Concentrations of Formaldehyde in the Inside Atmosphere of Industrial Premises." Gigiena Truda i Professional'nye Zabolevaniya [Russian] 12:16-20.

Zannini, D., and L. Russo, 1957. "Consequences of Acute Intoxications Due to Gaseous Irritants of the Respiratory System." Lavoro Umano [Italian] 9:241-253.

Zenz, C., ed., 1980. Developments in Occupational Medicine. Chicago: Year Book Medical Publishers, Inc. pp. 349-353.

CHAPTER 3

POPULATION AT RISK FROM FORMALDEHYDE EXPOSURE

Factors that affect individuals' exposure to formaldehyde may be divided into two broad categories--product factors (characteristics that affect the emissions or offgassing of formaldehyde from the product) and spatial-temporal factors (location of the individual at the time of exposure). Under differing conditions, a product or production process is likely to emit formaldehyde at different rates. Furthermore, locations differ with respect to their capacity for trapping and holding formaldehyde. The interaction of these factors causes formaldehyde exposure to reflect individual lifestyles to a large extent.

In this chapter, exposures from production processes and from use of products containing formaldehyde are examined. An attempt is made to estimate exposures for various subgroups of the population. Primarily, these exposure estimates are applicable only to the inhalation pathway, though the ingestion and skin contact exposure pathways occur in some production processes and some product uses. It is important to note that the estimates provided use existing data and are not based on an original survey.

Section 3.1 provides estimates of formaldehyde concentrations in the ambient environment and indoors. Both workplace and residential concentrations are estimated. Section 3.2 provides time allocation profiles for population subgroups. Formaldehyde exposure profiles by time of day and cumulatively are presented for the population subgroups in Section 3.3. Finally, estimates of the exposures of the entire U.S. population are provided in Section 3.4.

3.1 FORMALDEHYDE CONCENTRATIONS

Both natural and human activities result in the presence of formaldehyde in the ambient (outdoor) and indoor environments. Formaldehyde concentrations in both environments are a function of the release rates of both formaldehyde and its precursors from their sources, and of factors which affect emissions rates and formaldehyde formation from precursors.

Formaldehyde is one of a class of pollutants predominantly generated by indoor sources. Outdoor sources have little impact on ambient concentrations of the pollutant. They are briefly reviewed below for completeness and because they affect background concentration. However, indoor concentrations may be significant, especially in tight, energy-efficient structures (Yocom, 1982).

3.1.1 Ambient Concentrations

Ambient levels of formaldehyde are determined by natural processes and by combustion and production processes which liberate formaldehyde and its precursors directly into the outdoor air. Factors such as amount of available sunlight, which affects photochemical processes; levels of hydrocarbons and free formaldehyde released during combustion or production; wind conditions affecting dispersion of emissions; and temperature and rainfall affecting rate of chemical processes are important to determination of ambient concentrations (National Research Council (NRC), 1981a; Versar, 1982).

3.1.1.1 Natural Sources and Ambient Concentrations--

Formaldehyde is present even in "clean" air due to natural processes that either directly release formaldehyde or cause its formation. Formaldehyde is a constituent of various fruits, vegetables, trees, and other vegetation where it may be given off in normal release or may be liberated through combustion of vegetative materials as may occur during a forest fire (NRC, 1981a). The incomplete combustion processes associated with volcanic eruptions are another source of formaldehyde as is the anaerobic decomposition of methane by bacteria and certain other microorganisms such as yeast (Versar, 1982).

Photochemical processes in the atmosphere generate HO radicals that react with hydrocarbons present in the atmosphere to create formaldehyde (NRC, 1981a). This process is estimated to be responsible for approximately 90,000 to 180,000 megagrams of formaldehyde annually (Oatway and Klemm, 1981). The photodissociation of alkyl nitrates also results in formaldehyde production (Oatway and Klemm, 1981).

Processes also exist that break down formaldehyde in the natural environment. Photolytic reactions and oxidation are two such mechanisms which break down formaldehyde in the air. Depending on the time of year, the time of day, and various meteorologic conditions, the normal half-life for formaldehyde is 4.6 hours to 11.4 hours (Versar, 1982).

The National Research Council (1981a) has summarized data indicating that aldehyde concentrations in clean air range from 0.0005 to 0.002 ppm. Formaldehyde is the dominant aldehyde. Versar (1982) estimates formaldehyde concentrations in rural places to average 0.0004 ppm. The NRC and Versar values may suggest the approximate natural ambient levels of formaldehyde in the atmosphere.

The presence of formaldehyde in water is negligible due to its rapid degradation in that medium (Versar, 1982). Formaldehyde penetrates deeply into sandy, loamy, and chernozem soils and is uniformly distributed. In clay soils absorption occurs most readily under dry, hot weather conditions. In most cases, soil formaldehyde content is negligible (Versar, 1982).

3.1.1.2 Man-Made Sources and Ambient Concentrations--

Combustion and production processes are the main contributors to formaldehyde in the ambient air both directly and indirectly. Direct production of formaldehyde, formaldehyde resins and chemicals, and uses of these products in production processes or as preservatives and disinfectants may liberate substantial amounts of formaldehyde directly into the air. Versar (1982) estimates that about 14,500 megagrams were released by these processes in 1980. Oatway and Klemm (1982) estimate 43,710 to 59,810 megagrams of formaldehyde are emitted annually.

The indirect production of formaldehyde is by far the largest source for air release of the chemical. Versar (1982) reports that 99 percent of the total identified airborne emissions for formaldehyde in 1980 are from indirect production sources, while Oatway and Klemm (1982) placed that figure annually at 90 percent. Indirect production results chiefly from photochemical reactions in the presence of hydrocarbons, such as are emitted in the combustion of fossil fuels and waste incineration. Processes included are combustion of fuel and diesel oil, aviation and automobile fuel, natural gas, coal, and oil, incineration of municipal and vegetative wastes, and oil refining (NRC, 1981a; Versar, 1982; Oatway and Klemm, 1982).

Certain other industrial processes which utilize fossil fuels have been evaluated for their formaldehyde emission. These range from amberglass and mineral wool manufacture to brakeshoe debonding (NRC, 1981a). In effect, any such fossil fuel emissions containing incompletely combusted hydrocarbons may serve as formaldehyde precursors.

The NRC data for polluted urban environments place aldehyde concentrations in the 0.01 to 0.05 ppm range during the daylight hours (NRC 1981a). Versar estimates urban concentrations to average 0.005 ppm. Using the NRC- and Versar-based estimates for natural ambient levels, human activity appears to account for virtually all ambient formaldehyde.

3.1.2 <u>Indoor Concentrations</u>

Formaldehyde is a potential constituent of indoor air. The primary places of exposure are in the workplace and the home.

3.1.2.1 Workplace Concentrations--

Significant formaldehyde concentrations in the workplace are found in establishments that manufacture or use formaldehyde, formaldehyde derivatives, and formaldehyde-releasing products. The key industries are shown in Table 3-1. Table 3-2 shows the estimates of workplace formaldehyde concentration levels for high exposure industries adopted for this report. They are primarily derived from Versar (1982). Other studies have also provided workplace exposure estimates. For example, the Snell Division of Booz, Allen, and Hamilton, Inc. performed a study for the Synthetic Organic Chemical Manufacturers Association in 1979. Exposure levels were based on a sensory perception scale utilizing probable concentration levels and ranges for odor and eye effects experienced by workers. Two later analyses criticized Snell for relying on a small sample with poor response rate (about 400 of 3,365 mailed surveys were returned). One of these was a workshop commissioned by the White House Office on Science and Technology Policy to address the toxicological aspects of formaldehyde (Consensus Workshop on Formaldehyde, 1983).

TABLE 3-1. USERS OF FORMALDEHYDE, FORMALDEHYDE DERIVIATIVES AND FORMALDEHYDE-RELEASING PRODUCTS

Industry	SIC Code	Product or service
Agriculture	0134	Potato farm operation
	0161	Onion farm operation
	0181	Ornamental bulb growing
	0181	Nursery and greenhouse operation
	0182	Mushroom farm operation
	0189	Garlic seed processing
	025	Producing and hatching of poultry eggs
	025	Poultry farm operation
	0711	Soil preparation
	0721	Crop planting, cultivating and protection
	0849	Sugar maple tree tapping
Mining	1381	Oil and gas well drilling
Construction	152	General residential contracting
	172	Painting contracting
	1742	Plastering, drywall, acoustical, and insulation work
	1751	Carpentering
	1752	Floor laying and other floorwork
Foods and Kindred Products	20	Food products
	201	Meat products
Manufacturing	226	Dyeing and finishing textiles
	2291	Felts goods, except woven felts and hats
	2295	Coated fabrics, not rubberized
	231	Men's, youths' and boys' suits, coats, and overcoats
	232	Men's, youths', and boys' furnishings, work clothing, and allied garments
	233	Women's, misses', and juniors' outerwear
	234	Women's, misses', children's, and infants' undergarments
	236	Girls', children's, and infants' outerwear
	237	Miscellaneous fabricated textile products
	242	Sawmills and planing mills
	2435	Hardwood veneer and plywood
	2436	Softwood veneer and plywood
	2451	Mobile homes
	2452	Prefabricated wood buildings
	2491	Wood preservatives
	2492	Particleboard
	251	Household furniture
	2521	Wood office furniture
	2531	Public building and related furniture

(continued)

TABLE 3-1 (continued)

Industry	SIC Code	Product or service
Manufacturing (continued)	2541	Wood partitions, shelving, lockers, and office and store fixtures
	2599	Furniture and fixtures
	261	Pulp mills
	2621	Paper, except building papers
	2631	Paperboard
	2641	Coated and glazed paper products
	2643	Paper bags
	2647	Sanitary paper products
	2653	Corrugated boxes
	2661	Building paper and building board
	27	Printing and publishing
	2751	Commercial printing
	2821	Plastics, materials, synthetic resins, and nonvulcanizable elastomers
	283	Drugs
	284	Soap, detergent and cleaning preparations, perfumes, cosmetics, and other toilet preparations
	2851	Paints, varnishes, lacquers, enamels, and allied products
	2865	Cyclic crudes, cyclic intermediates, dyes, and organic pigments
	2869	Industrial organic chemicals, NEC[a]
	2873	Nitrogenous fertilizers
	2879	Pesticides and agricultural chemicals, NEC[a]
	2891	Adhesives and sealants
	2899	Chemicals and chemical preparations
	2911	Petroleum refining
	2952	Asphalt felt and coatings
	3011	Tires and inner tubes
	3069	Fabricated rubber products, NEC[a]
	3079	Urea-formaldehyde foam resins, phenol-formaldehyde resin insulation foams, and miscellaneous plastic products
	3111	Leather tanning and finishing
	314	Shoes
	3231	Mirrors
	327	Concrete, plaster, and related products
	3291	Abrasive products
	3292	Asbestos products
	3296	Mineral wool insulation
	332	Iron and steel foundries
	336	Nonferrous foundries
	3471	Electroplating, plating, polishing, anodizing, and coloring

(continued)

TABLE 3-1 (continued)

Industry	SIC Code	Product or service
Manufacturing (continued)	3479	Coating, engraving, and allied services, NEC[a]
	3565	Industrial patterns
	3634	Electric housewares and fans
	364	Electric lighting and wiring equipment
	366	Communication equipment
	3679	Electric components, NEC[a]
	3694	Electrical equipment for internal combustion engines
	3714	Motor vehicles parts and accessories
	3728	Aircraft parts and auxiliary equipment
	3732	Boat building and repairing
	3792	Travel trailers and campers
	3861	Photographic equipment and supplies
	394	Toys and amusement, sporting, and athletic goods
	3963	Buttons
Wholesale Trade	4221	Citrus storage facility operation
	5031	Lumber, plywood and millwork
	513	Apparel
	516	Chemicals and allied forms
Retail Trade	5211	Lumber and other building materials
	5271	Mobile homes
	56	Apparel and accessories
	571	Furniture, home furnishings and equipment
Services	721	Laundry, cleaning and garment services
	7231	Beauty shop services
	724	Barber shop services
	7261	Funeral services
	7342	Disinfecting and exterminating services
	7391	Research and development laboratory work
	7395	Photofinishing laboratory work
	7641	Reupholstery and furniture repair
	80	Health-related facility cleaning and maintenance services
	806	Hospital services
	8071	Medical laboratory work
	8072	Dental laboratory work
	821, 822	High school, college, and professional school biology teaching

[a]Not elsewhere classified.

See Sources on following page.

TABLE 3-1 (continued)

SOURCES: 1. Hattis, Dale, Clifford Mitchell, Janet McCleary-Jones, and Nancy Gorelick, 1981. Control of Occupational Exposures to Formaldehyde: A Case Study of Methodology for Assessing the Health and Economic Impacts of OSHA Health Standards. Report No. CPA-81-17. Bedford, Massachusetts: Center for Policy Alternatives, Massachusetts Institute of Technology.

2. Snell Division, 1979. Preliminary Study of the Costs of Increased Regulation of Formaldehyde Exposure in the U. S. Workplace. Prepared for Formaldehyde Task Force of the Synthetic Organic Chemical Manufacturers Association. Florham Park, New Jersey: Booz, Allen, Hamilton, Inc. pp. 359-364.

3. Versar, Inc., 1982. Exposure Assessment for Formaldehyde. Final Draft Report. Contract No. 68-01-6271. Prepared for Office of Toxic Substances, Environmental Protection Agency. Springfield, Virginia: Versar, Inc. Tables 5, 6, 8 in Appendix A. n.p.

TABLE 3-2. WORKPLACE CONCENTRATIONS OF FORMALDEHYDE

Industry	Average concentration (ppm)[a]
Formaldehyde manufacturing	0.46 (0.04 - 2.20)
Urea, phenol, melamine and acetal formaldehyde resin manufacturing	1.40 (0.05 - 1.70)
Hardwood plywood manufacturing	0.68 (0.09 - 1.50)
Particleboard manufacturing	1.15 (0.10 - 4.90)
Wood furniture manufacturing	1.30 (0.07 - 5.17)
Mobile home manufacturing	0.40 (n.a.)
Urea formaldehyde foam chemicals manufacturing	0.49 (0.04 - 5.17)
Urea formaldehyde foam insulation installation	0.52 (< 0.03 - 2.40)
Metal molds and castings manufacturing	0.33 (0.02 - 18.30)
Plastic products manufacturing	0.26 (< 0.01 - 4.00)
Paper and paperboard manufacturing	0.15 (0.01 - 0.99)
Textiles manufacturing	0.42 (< 0.1 - 1.40)
Apparel manufacturing	0.64 (< 0.1 - 1.80)
Apparel wholesaling	0.38 (0.04 - 0.73)
Building paper and board manufacturing	1.15 (0.10 - 4.90)

(continued)

TABLE 3-2 (continued)

Industry	Average concentration (ppm)[a]
Paints and coatings manufacturing	0.12[d] (0.08 - 0.15)
Abrasive products manufacturing	1.10 (n.a.)
Asbestos products manufacturing	1.10 (n.a.)
Urea formaldehyde concentrates manufacturing	0.46 (0.04 - 2.20)
Nitrogenous fertilizer manufacturing	0.84 (0.20 - 1.90)
Other large volume formaldehyde derivatives manufacturing	0.46 (0.04 - 2.20)
Poultry egg producing and hatching	1.70 (0.20 - 3.99)
Mushroom farm operation	0.32 (< 0.02 - < 10.0)
Disinfecting and cleaning service contracting	0.38 (0.05 - 3.50)
Service work in health-related facilities	0.38 (0.05 - 3.50)
Medical and pathology laboratory work	0.85 (0.06 - 8.00)
Dental laboratory work	0.03 (n.a.)
High school biology teachers	5.30 (2.70 - 8.30)
High school biology students	5.30 (2.70 - 8.30)
College and university biology teachers	5.30 (2.70 - 8.30)

(continued)

TABLE 3-2 (continued)

Industry	Average concentration (ppm)[a]
College and university biology students, medical students, nursing students, and dental students	5.30 (2.70 - 8.30)
Funeral service work	1.70 (0.20 - 3.99)
Metalwork machine operation	0.16 (0.05 - 1.20)

[a]Range of exposures in parentheses. n.a. = not available

[b]Reference for average exposure is Oatway and Klemm (1981). All others are Versar, Inc. (1982).

SOURCES:

1. Oatway, Janet, and Hans A. Klemm, 1981. Formaldehyde Regulatory Control Options Analysis. Draft Final Report. Contract No. 68-01-5960. Prepared for Office of Chemical Control, Environmental Protection agency. Report No. GCA-TR-81-1-G. Bedford, Massachusetts: GCA Corportion.

2. Versar, Inc., 1982. Exposure Assessment for Formaldehyde. Final Draft Report. Contract No. 68-01-6271. Prepared for Office of Toxic Substances, Environmental Protection Agency. Springfield, Virginia: Versar, Inc. pp. 67-69.

The Consensus Workshop on Formaldehyde met and reviewed pertinent literature, including that on exposure. They concluded that there is not enough data to characterize temporal or within-plant variation of any occupation, or even describe exposure for more than a few plants in any one industry. Furthermore, available data are not representative enough to establish the ranges of exposures present in industry. Differences may be substantial between industrial and professional workers with regard to the nature of their exposures. Though available monitoring data was considered reasonably reliable, it is available only for 34 job categories in 29 industries and occupations. Thus the data in Table 3-2 should be cautiously interpreted.

The Center for Policy Alternatives at the Massachusetts Institute of Technology performed a study of control costs of alternative regulations on formaldehyde in industry (Hattis et al., 1981). This study provided frequency distributions of the percentage of complaints related to formaldehyde at different concentrations in the workplace. This distribution method provides a refinement for assessing exposure, since the concentration of formaldehyde is not assumed the same for all workers in an industry.

Although more realistic, the industry groups used by Hattis et al. (1981) are too aggregated and no guidance is given as to a "best" estimate of the total numbers of workers exposed. A combination of this approach and the Versar (1982) method would provide an appropriate data base for future investigations.

Concentrations of formaldehyde vary in different locations within an establishment. A person's occupation can provide a guide to where the concentrations may be found. The National Institute of Occupational Safety and Health (NIOSH) (1981) identified 225 occupations involving exposure to formaldehyde (see Table 3-3).

3.1.2.2 Residential Concentrations--

Formaldehyde concentrations in the home depend on the existence of formaldehyde in consumer products, the rate of formaldehyde release or off-gassing from the products, the type and extent of human activities, and the extent to which the dwelling and activities of the residents result in exchange of the indoor air (Yocom, 1982; National Research Council [NRC], 1981b).

TABLE 3-3. OCCUPATIONS INVOLVING EXPOSURE TO FORMALDEHYDE

Accountants
Adult Education Teachers
Advertising Agents and Salesmen
Aeronautical and Astronautical Engineers
Agriculture and Biological Technicians
Air Conditioning, Heating, and Refrigeration
Aircraft
Animal Caretakers, Except Farm
Archivists and Curators
Asbestos and Insulation Workers
Assemblers
Automobile Body Repairmen
Automobile Mechanics
Bakers
Bank Tellers
Barbers
Bartenders
Billing Clerk
Biological Scientists
Bookbinders
Bookkeepers
Bookkeeping and Billing Machine Operators
Bootblacks
Bottling and Canning Operatives
Brickmasons and Stonemasons
Bus Drivers
Busboys
Cabinetmakers
Carpenter Apprentices
Carpenters
Carpenters' Helpers
Carpet Installers
Cashiers
Cement and Concrete Finishers
Chambermaids and Maids, Except Private Household
Checkers, Examiners, and Inspectors; Manufacturers
Chemical Technicians
Chemists
Child Care Workers, Except Private Household
Cleaners and Charwomen
Clerical Supervisions, N.E.C.
Clerical Workers - Miscellaneous
Clerical Workers - Not Specified
Clinical Laboratory Technologists and Technicians
Clothing Ironers and Pressers
Compositors and Typesetters
Computer and Peripheral Equipment Operators
Computer Programmers
Computer Specialists, N.E.C.
Construction Laborers, Except Carpenters' Helper
Cooks, Except Private Household
Counter Clerks, Except food
Craftsmen and Kindred Workers, N.E.C.
Cranemen, Derrickmen, and Hoistmen
Credit men
Cutting Operatives, N.E.C.
Decorators and Window Dressers
Dental Assistants
Dental Hygienists
Dental Laboratory Technicians
Dentists
Designers
Dishwashers
Draftsmen
Dressmakers and Seamstresses, Except Factory
Drill Press Operatives
Dry Wall Installers and Lathers
Duplicating Machine Operators
Dyers
Editors and Reporters
Electric Power Linemen and Cablemen
Electrical and Electronic Engineering Technicians
Electrical and Electronic Engineers
Electrician Apprentices
Electricians
Elevator Operators
Embalmers
Engineering and Science Technicians, N.E.C.
Engineers, N.E.C.
Engravers, Exc. Photoengravers
Estimators and Investigators, N.E.C.
Expediters and Production Controllers
File Clerk
Filers, Polishers, Sanders, and Buffers
Food Counter and Fountain Workers
Food Service Workers, N.E.C., Except Private
Foremen, N.E.C.
Fork Lift and Tow Motor Operatives
Freight and Material Handlers
Funeral Directors
Furnacemen, Smeltermen, and Pourers
Furniture and Wood Finishers
Garage Workers and Gas Station Attendants
Gardeners and Groundskeepers, Exc. Farm
Geologists
Glaziers
Graders and Sorters, Manufacturing
Grinding Machine Operatives
Guards and Watchmen
Hairdressers and Cosmetologists
Health Administrators
Health Aides, Except Nursing
Health Record Technologists and Technicians
Health Technologists and Technicians, N.E.C.
Heat Treaters, Annealers, and Temperers
Heavy Equipment Mechanics, Including Diesel
Household Appliance and Accessory Installers
Housekeepers, Except Private Household
Industrial Engineering Technicians
Industrial Engineers
Inspectors, N.E.C.
Insurance Adjusters, Examiners, and Investigators
Insurance Agents, Brokers, and Underwriters
Janitors and Sextons
Jewelers and Watchmakers
Job and Die Setters, Metal
Key Punch Operators
Laborers - Miscellaneous
Laborers - Not Specified
Lathe and Milling Machine Operatives
Laundry and Dry Cleaning Operatives, N.E.C.
Librarians
Loom Fixers
Machine Operatives - Miscellaneous Specified
Machine Operatives - Not Specified
Machinists
Mail Handlers, Except Post Office
Managers and Administrators, N.E.C.
Meat Cutters and Butchers, Except Manufacturing
Meat Cutters and Butchers, Manufacturing
Mechanic, Exc. Auto, Apprentices
Mechanical Engineers
Mechanics and Repairmen - Miscellaneous
Mechanics and Repairmen - Not Specified
Metal Platers
Millwrights
Mine Operatives, N.E.C.
Mixing Operatives
Molders, Metal
Motion Picture Projectionists
Nursing Aides, Orderlies, and Attendants
Office Machine Operators, N.E.C.
Office Managers, N.E.C.
Officers, Pilots, and Pursers; Ship
Oilers and Greasers, Exc. Auto
Operations and Systems Researchers and Analysers
Operatives - Miscellaneous
Operatives - Not Specified
Opticians, and Lens Grinders and Polishers
Packers and Wrappers, Except Meat and Produce
Painters and Sculptors
Painters, Construction and Maintenance
Painters, Manufactured Articles
Pattern and Model Makers, Except Paper
Payroll and Timekeeping Clerks
Personal Service, N.E.C. - Attendants
Personnel and Labor Relations Workers
Pharmacists
Photoengravers and Lithographers
Photographers
Photographic Process Workers
Physicians, Medical and Osteopathic
Plumbers and Pipe Fitters
Podiatrists
Practical Nurses
Precision Machine Operatives, N.E.C.
Pressmen and Plate Printers, Printing
Pressman Apprentices
Punch and Stamping Press Operatives
Purchasing Agents and Buyers, N.E.C.
Radio and Television
Radiologic Technologists and Technicians
Receptionists
Recreation and Amusement - Attendants
Recreation Workers
Registered Nurses
Research Workers, not specified
Restaurant, Cafeteria, and Bar Managers
Riveters and Fasteners
Sailors and Deckhands
Sales Managers and Department Heads, Retail Trade
Sales Managers, Except Retail Trade
Salesmen and Sales Clerks, N.E.C.
Sawyers
Secretaries, N.E.C.
Sheetmetal Workers and Tinsmiths
Shipping and Receiving Clerks
Shoe Repairmen
Shoemaking Machine Operatives
Sign Painters and Letterers
Social Workers
Solders
Specified Craft Apprentices, N.E.C.
Spinners, Twisters, and Winders
Stationary Engineers
Stationary Firemen
Statistical Clerks
Statisticians
Stenographers
Stock Clerks and Storekeepers
Stock Handlers
Tailors
Teachers, Except College and University, N.E.C.
Technicians, N.E.C.
Telephone Installers and Repairmen
Telephone Linemen and Splicers
Telephone Operators
Textile Operatives, N.E.C.
Therapists
Therapy Assistants
Ticket, Station, and Express Agents
Tile Setters
Tool and Die Maker Apprentices
Tool and Die Makers
Truck Drivers
Typists
Upholsterers
Vehicle Washers and Equipment Cleaners
Veterinarians
Waiters
Warehousemen, N.E.C.
Weighers
Welders and Flame-cutters
Winding Operatives, N.E.C.
Writers, Artists, and Entertainers, N.E.C.

N.E.C. – Not Elsewhere Classified.

Source: National Institute for Occupational Safety and Health (NIOSH), 1981. *Formaldehyde: Evidence of Carcinogenicity.* Current Intelligence Bulletin No. 34. U.S. Department of Health and Human Services. p. 9.

Table 3-4 provides a partial list of products which may contain formaldehyde. There are a multitude of others, many of which can be identified from Table 3-1, as products of industries which utilize formaldehyde or formaldehyde by-products.

A number of factors may affect the emissions from formaldehyde-containing products. These include:

- Amount of formaldehyde used in product
- Temperature
- Humidity
- Time of day
- Season of year
- Type of formaldehyde used in product
- Extent of formaldehyde-containing products
- Age of product
- Exposed surface area of product.

The amount and type of formaldehyde in a product significantly affects release rates. In many applications, urea-formaldehyde is added to products as a cross-linking or polymerization agent. As such, any excess formaldehyde causes faster reactions but also leaves excess unreacted formaldehyde in the final consumer product. This formaldehyde is then available for release in such products as particleboard, indoor plywood, paper products, permanent-press and flame-retardent textiles, and foams used as insulation (NRC, 1981a).

Other forms of formaldehyde in common use in consumer products include phenolic- and melamine-formaldehydes. Both forms are more resistant to degradation and subsequent release of free-formaldehyde than is urea-formaldehyde (Versar, 1982). Cost considerations and suitability for particular products determine their use.

Temperature and humidity often work together to affect the release of formaldehyde from products. High temperatures and high humidities are conductive to formaldehyde offgassing in many products (Pickerall et al.,

Table 3-4. CONSUMER PRODUCTS CONTAINING FORMALDEHYDE

Adhesives	Insulation, foam and others
Automobile appliances	Intermediate chemicals
Brake linings	Laminates
Buttons	Leathers, Fur, and Hair
Carpet	Lubricants, synthetic
Clothing	Mildewcides
Cosmetics	Paints
Deodorants	Paper and Paper goods
Detergents	Particleboard
Dinnerware	Pesticides
Drapery	Pharmaceuticals
Dyes	Plastics and Plastics moldings
Electrical components	Plywood
Embalming fluid	Printing
Explosives	Rubber products
Fertilizers	Sporting equipment
Fiberboard	Surface coatings
Filters	Textiles
Food	Toiletries
Friction materials	Upholstery
Fuels	Urethane resins
Fungicides	Watersoftening chemicals
Hardware, garden	

SOURCES:

1. Cosmetic Ingredient Review (CIR), 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology v. 3. No. 3. pp. 161-162.

2. Pickerall, J. A., L. C. Griffis, and C. H. Hobbs, 1982 Release of Formaldehyde from Various Consumer Products. Final Report. Report No. LMF-93, UC-48. Prepared for Consumer Products Safety Commission. Albuquerque, New Mexico: Lovelace Biomedical and Environmental Research Institute. p. 3.

3. National Institute of Occupational Safety and Health (NIOSH), 1981. Formaldehyde: Evidence of Carcinogenicity. Current Intelligence Bulletin No. 34. U. S. Department of Health and Human Services. p. 2.

4. Versar, Inc., 1982. Exposure Assessment for Formaldehyde. Final Draft Report. Contract No. 68-01-6271. Prepared for Office of Toxic Substances, Environmental Protection Agency. Springfield, Virginia. pp. 22-33.

1982; Yocom, 1982). It has been shown that time of day and season of year reflect changing temperature, humidity, and human activity which in turn influence release rates of formaldehyde from products used in construction and household uses (Gammage, 1981; Gammage et al., 1983; Hawthorne et al., 1983).

The extent of formaldehyde-containing products in the home would obviously affect indoor concentrations of formaldehyde. In particular, a new mobile home has higher concentrations of formaldehyde than does a conventional home on average because so much of the interior of a mobile home is composed of pressed wood products (Dally et al., 1981; Versar, 1982).

More than one formaldehyde-containing product may be in use within a given area at the same time. This could occur, for example, in a home that contains urea-formaldehyde foam insulation (UFFI) in the walls and is furnished with formaldehyde-containing draperies, carpets, and particleboard furniture. Interactions of various combinations of particleboard, plywood, insulation, and carpet tested by Pickerall et al. (1982) reveal that formaldehyde release is lower for two products together than for the sum of their individual release rates. Further investigation is needed in this area.

Age of products may give some indicator of their ability to release free formaldehyde, since exposure of the product to temperature and humidity will eventually eliminate most of the free formaldehyde from the product. Investigation of homes containing UFFI by Gammage et al. (1983), Hawthorne et al. (1983), and Dally et al. (1981) have confirmed this result. A summary of monitoring data by the National Research Council (1981a) indicated that an approximate value for the half-life of formaldehyde is 4.4 years.

The exposed surface area of a product such as particleboard or plywood in relation to the space and ventilation available in a closed area can affect the release rates (Bardana, 1980). Release rates are considered most meaningful if expressed in relation to lateral surface area of a product (Pickerall et al., 1982).

In a home, human activities such as cooking or heating with gas fuel and smoking add substantially to indoor formaldehyde levels (Hawthorne et al., 1983; NRC, 1981a; Yocom, 1982; Gammage et al., 1983). Structural characteristics such as energy-efficient modifications create an environment which holds more of the formaldehyde, increasing exposure without influencing offgassing of particular products. Attitudes toward ventilation by the residents and the amount of traffic in and out of the home also affect indoor air exchange rates.

Table 3-5 lists emissions rates for several consumer products and activities. Among those products with comparable units of measure (i.e., those with emission rates measured in $\mu g/m^2/day$), a relative ranking is: pressed wood products >> clothes ~ insulation products ~ paper products > fabric > carpet (Pickerall et al., 1982).

Pickerall et al. (1982) evaluated the relative emission rates of several products. Products with formaldehyde offgassing rates less than 50 to 100 $\mu g/m^2/day$ represent very low levels, and may be considered to approximate a zero release coefficient. These would include drapery fabric (77 percent rayon/23 percent cotton), all types of upholstery fabric tested (100 percent nylon, 100 percent olefin, and 100 percent cotton), some samples of latex-backed fabric, blend fabric, some samples of childrens' clothing (65 percent polyester cotton/35 percent cotton), and some carpet tested.

Very low offgassing rates, compared to the highest rate found for all products, were those less than 340 $\mu g/m^2/day$. This includes some plywood, some fiberglass insulation, some paper products, some drapery fabric (100 percent cotton), and girls' polyester/cotton dresses, as well as those in the zero release category mentioned above.

Combustion in gas stoves and cigarettes may be substantial sources of indoor formaldehyde (NRC, 1981a). The number of cigarettes smoked and number of times and duration of gas stove use may be directly converted to additional formaldehyde in the indoor environment.

The presence of formaldehyde in food is nonanthropogenic, originating instead from processes the foods undergo in preparing them for consumption (Versar, 1982). The freezing process increases formaldehyde levels found in fish, while autooxidation caused by the deboning process elevates formaldehyde concentrations in mechanically deboned turkey. Maple syrup products may be contaminated with formaldehyde from paraformaldehyde pellets placed

TABLE 3-5. FORMALDEHYDE EMISSIONS FROM VARIOUS CONSUMER PRODUCTS

Product	Emission rate ($\mu g/m^2/day$)	Reference
Particleboard	1,800 - 28,000	1
Plywood	54 -15,000	1
Paneling	1,480 - 36,000	1
Fiberglass insulation	52 - 620	1
Paper plates and cups	75 - 1,000	1
Drapery fabric		
100% cotton	90 - 350	1
77% rayon/23% cotton	ND[a] - 50	1
Upholstery fabric		
100% nylon	6 - 11	1
100% olefin	ND[a] - 5	1
100% cotton	ND[a]	1
Latex-backed fabric	ND[a] - 100	1
Blend fabric	20 - 30	1
New, unwashed clothes		
Men's shirts		
65% polyester cotton/35% cotton	380 - 550	1
Ladies' dresses	380 - 750	1
Girl's dresses		
polyester/cotton	120 - 140	1
Child's clothes		
65% polyester cotton/35% cotton	15 - 55	1
Carpets	ND[a] - 65	1
Gas stove		
Top burner	15,000 μg/hr	2
	11.4 μg/Kcal	3
Oven	25,000 μg/hr	2
	7.1 μg/Kcal	3
Cigarettes	0.02 - 0.04 mg/cig	2
Food products[b]		
Fish (frozen products)	1.1 ppm	4
Turkey (mechanically deboned)	0.7 ppm	4
Maple syrup products	2.0 ppm	4
Red meat	unknown	4

See footnotes on following page.

TABLE 3-5 (continued)

[a]ND = not detectable.

[b]Units are for formaldehyde contents in the product, rather than emission rates from the product.

SOURCES: 1. Pickerall, J. A., L. C. Griffis, and C. H. Hobbs, 1982. Release of Formaldehyde from Various Consumer Products. Final Report. Report No. LMF-93, UC-48. Prepared for Consumer Products Safety Commission. Albuquerque, New Mexico: Lovelace Biomedical and Environmental Research Institute. pp. 28-30.

2. National Research Council (NRC), 1981. Formaldehyde and Other Aldehydes. Washington, D.C.: National Academy Press. pp. 82-84.

3. Yocom, John E., 1982. "Indoor-Outdoor Air Quality Relationships - A Critical Review." Journal of the Air Pollution Control Association v. 32. No. 5. p. 516.

4. Versar, Inc., 1982. Exposure Assessment for Formaldehyde. Final Draft Report. Contract No. 68-01-6271. Prepared for Office of Toxic Substances, Environmental Protection Agency. Springfield, Virginia: Versar, Inc. p. 64.

in tap holes during sap collection to prevent fermentation. Red meats may contain formaldehyde due to the practice of feeding treated casein to ruminants (Versar, 1982; Cosmetic Ingredient Review [CIR], 1984).

Food may come in contact with formaldehyde through sealing devices containing paraformaldehyde and with disinfectants containing formaldehyde (Hattis et al., 1981; CIR, 1984). Food additives such as defoaming agents containing formaldehyde are permitted by law (CIR, 1984). There has so far been no attempt we are aware of to classify these foods or to assess their consequent contribution to human exposure.

Building materials such as plywood and particleboard treated with urea-formaldehyde resins and UFFI have the greatest potential for creating elevated levels of formaldehyde in the home. (Concensus Workshop on Formaldehyde, 1983; Versar, 1982; Pickerall et al., 1982). Transient elevations in formaldehyde concentration may be expected where gas stoves or space heaters are used, and where smoking takes place (Yocom, 1982; Consensus Workshop on Formaldehyde, 1983).

For this report, longterm rather than transient concentrations are considered of primary importance. High exposure and low exposure for consumer goods are determined in context with the home environment. High exposure homes include those conventional homes containing UFFI, and newer mobile homes, presumed to be constructed with substantial amounts of urea-formaldehyde containing wood products, which have not yet aged enough to significantly reduce exposures. This is generally considered to be the half-life of formaldehyde. Low exposure homes include all other dwellings.

For high exposure homes, the assumed formaldehyde concentration is 0.40 ppm, which represents an average level for new mobile homes and conventional homes containing UFFI (NRC, 1981a). Low exposure homes are assumed to have formaldehyde concentrations of 0.05 ppm (Consensus Workshop on Formaldehyde, 1983).

It should be noted that the many factors outlined above prevent specific estimates of exposure in homes. Proper estimation of actual exposures in homes would require monitoring or estimated data which take these factors into account, and at minimum provide categories of exposure ranges which can be expected under specified conditions.

3.2 ALLOCATION OF TIME

Exposure to formaldehyde is a function of the proximity of people to the places where formaldehyde concentrations exist. Locations, and consequently exposures, vary with activities. Activities vary with time of day, day of week or year, and year of lifetime, with age, sex, occupation, weather, race, and socioeconomic status (Spengler and Colome, 1982; Szalai, 1972; Robinson, 1977a; Robinson, 1977b; Chapin, 1974; Chapin and Brail, 1969; Hammer and Chapin, 1972; Brail and Chapin, 1973; NRC, 1981b).

An individual makes choices as to how his or her time will be spent in a twenty-four hour period. Time may be viewed as a resource used by the individual in satisfying wants and needs. The activities an individual selects may be viewed as functional classes from which an individual derives utility (Brail and Chapin, 1973). Time may be considered an input which is equally distributed (over the course of a day, at least) among all individuals (Robinson, 1977a). Inequalities arise in a given day only through "productivity levels" of individuals, and over a lifetime by the number of years in that lifetime.

Becker (1965) argued that time use entails both direct and indirect costs. These costs are measurable since time used is associated with foregone earnings which might have accrued from a different use of time, such as producing some good. It may be seen in this context that exposure levels are, to a significant extent, actually chosen by the selection of activities and locations where those activities will take place. Of course, enhanced awareness of individuals as to exposures associated with time choices and the effects of exposures may act to alter those choices.

In this report, we construct time usage profiles for selected population subgroups based on available data and populations of interest for formaldehyde exposure. Twenty-four hour time weighted averages of exposure and cumulative average exposures are also calculated.

3.2.1 Population Subgroups

Time allocation studies require the grouping of events into activity classes, and the grouping of subjects into population classes (Brail and Chapin, 1973). In this report, three prototype subgroups were evaluated, based on data collected from forty-four U.S. cities in a major international study conducted in 1964-1965 (Szalai, 1972). Surveys were administered to evaluate amount of time spent for various activity subclasses, the location of the activities, and the time of day (where a day in defined as a twenty-four hour period) at which the activities occurred.

The three subgroups were "employed men," "employed women," and "housewives." The total sample size was 872, broken down into 375, 246, and 251 persons in the respective categories. Each individual gave descriptions of their activities for one or two days of the week. From this data set, time profiles for each subgroup were constructed.

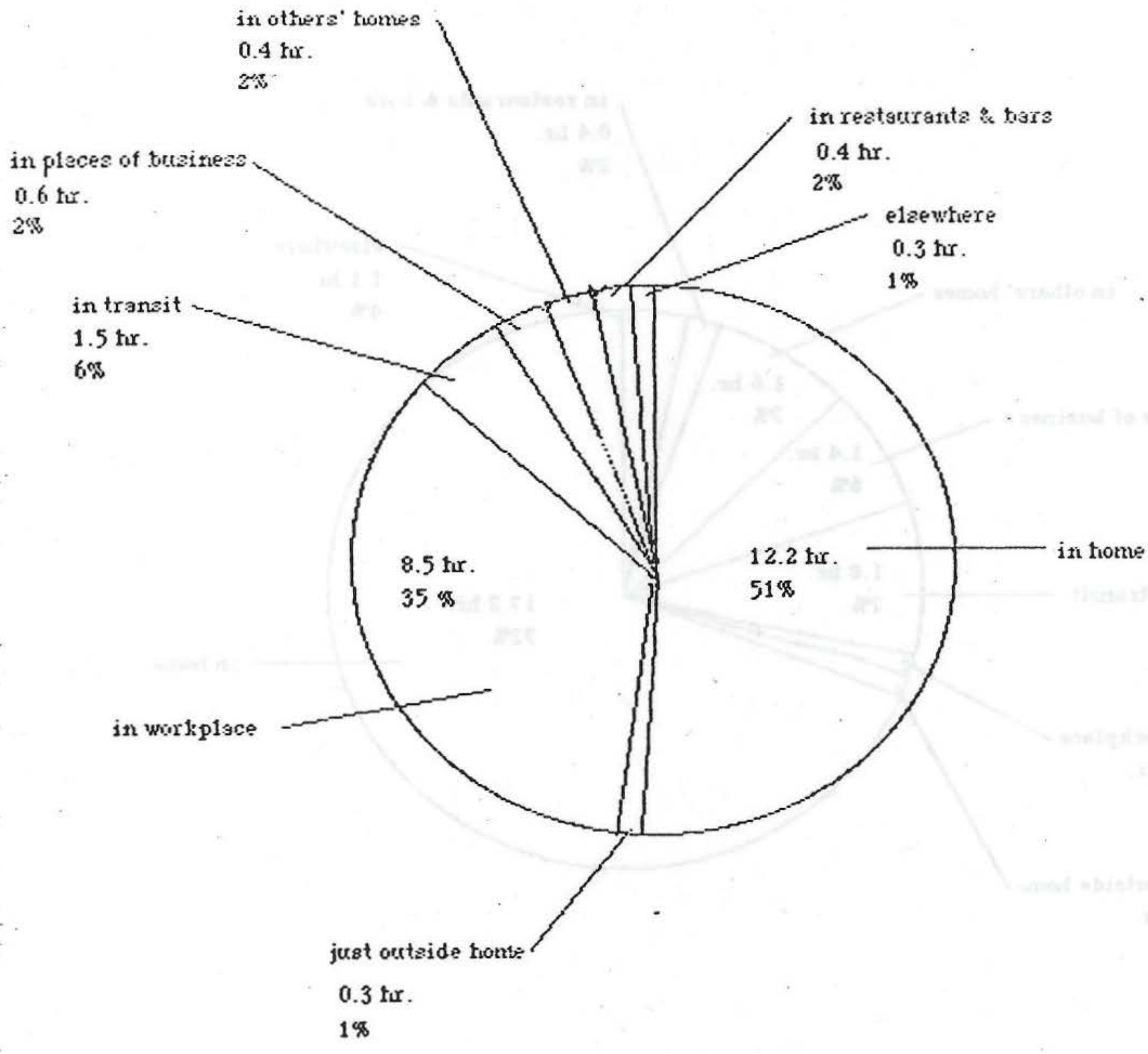
This data set is utilized in this report, with assumptions made about other relevant subgroups (such as young children and the elderly) as to their allocation of time. These assumptions are explained in Section 3.3 and Section 3.4 where formaldehyde exposure profiles are constructed for the entire U.S. population.

3.2.2 Time Profiles

The five-day work week is a major structuring element in time allocation. Weekdays and weekend days are two major classes used to subdivide time for working populations (Brail and Chapin, 1973; Hammer and Chapin, 1972). For children attending school, this structure may be modified to schooldays and nonschooldays, which occur on weekend days, holidays, and summertimes. For housewives and others who are not employed outside the home, a more useful structure centers around a division between Sundays and other days (Szalai, 1972).

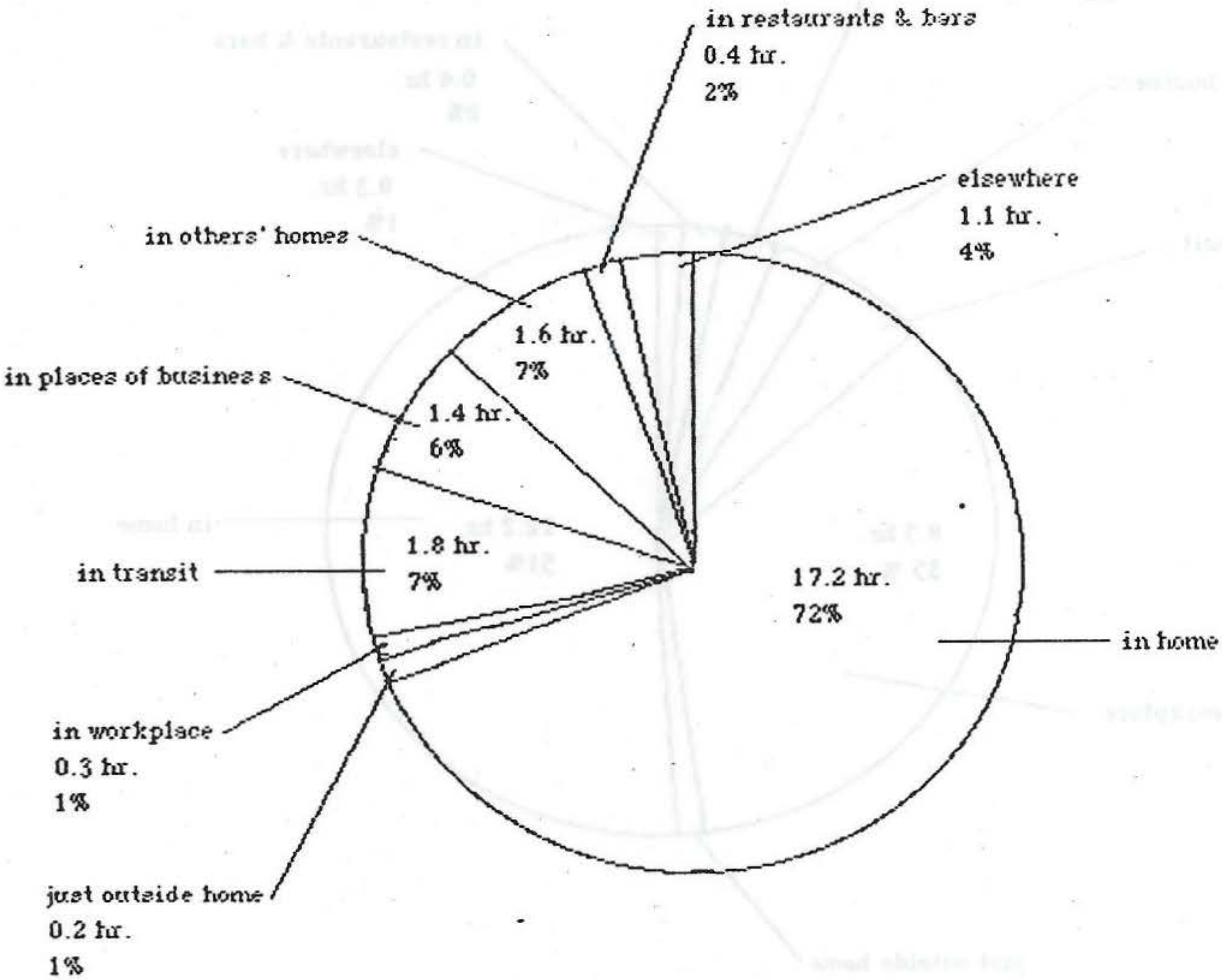
Time profiles for each of these subgroups are shown in Figures 3-1 through 3-8. These time profiles indicate where individuals spend their time for average twenty-four hour periods for the week divisions described above. Except for the subgroup of school age children, these figures are constructed from the data published in Szalai (1972).

One immediate conclusion is that individuals in the U.S. population subgroups described spend a substantial amount of time in homes, from 12 to 20 hours per day, depending on day of week. For those who work, at least seven hours a day are spent at the workplace, which for many individuals is



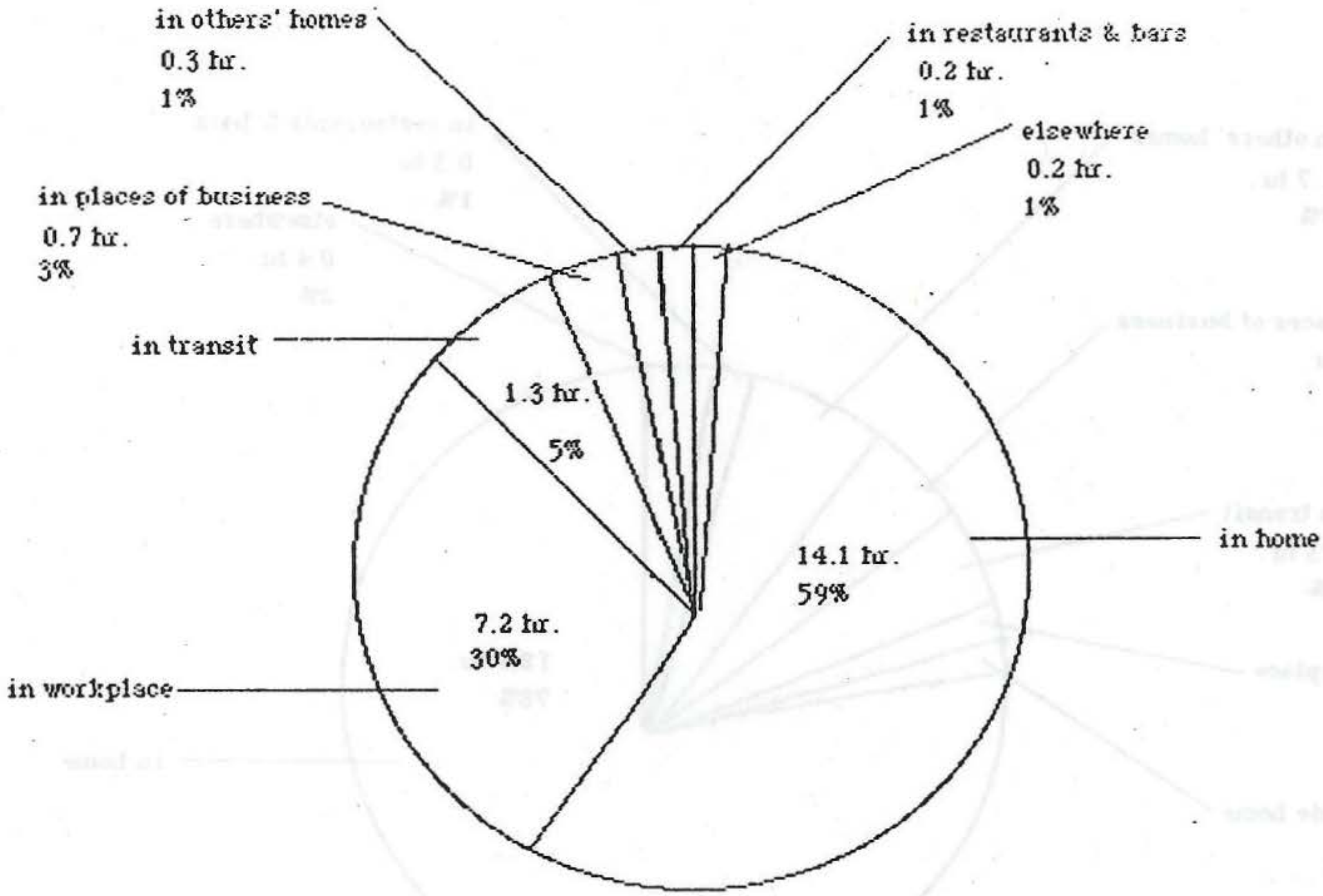
SOURCE: Szalai, Alexander, ed., 1972. The Use of Time. The Hague, Netherlands: Mouton. pp. 795-799.

Figure 3-1. Spatial allocation of time: employed males—workday.



SOURCE: Szalai, Alexander, ed., 1972. The Use of Time. The Hague, Netherlands: Mouton. pp. 795-799.

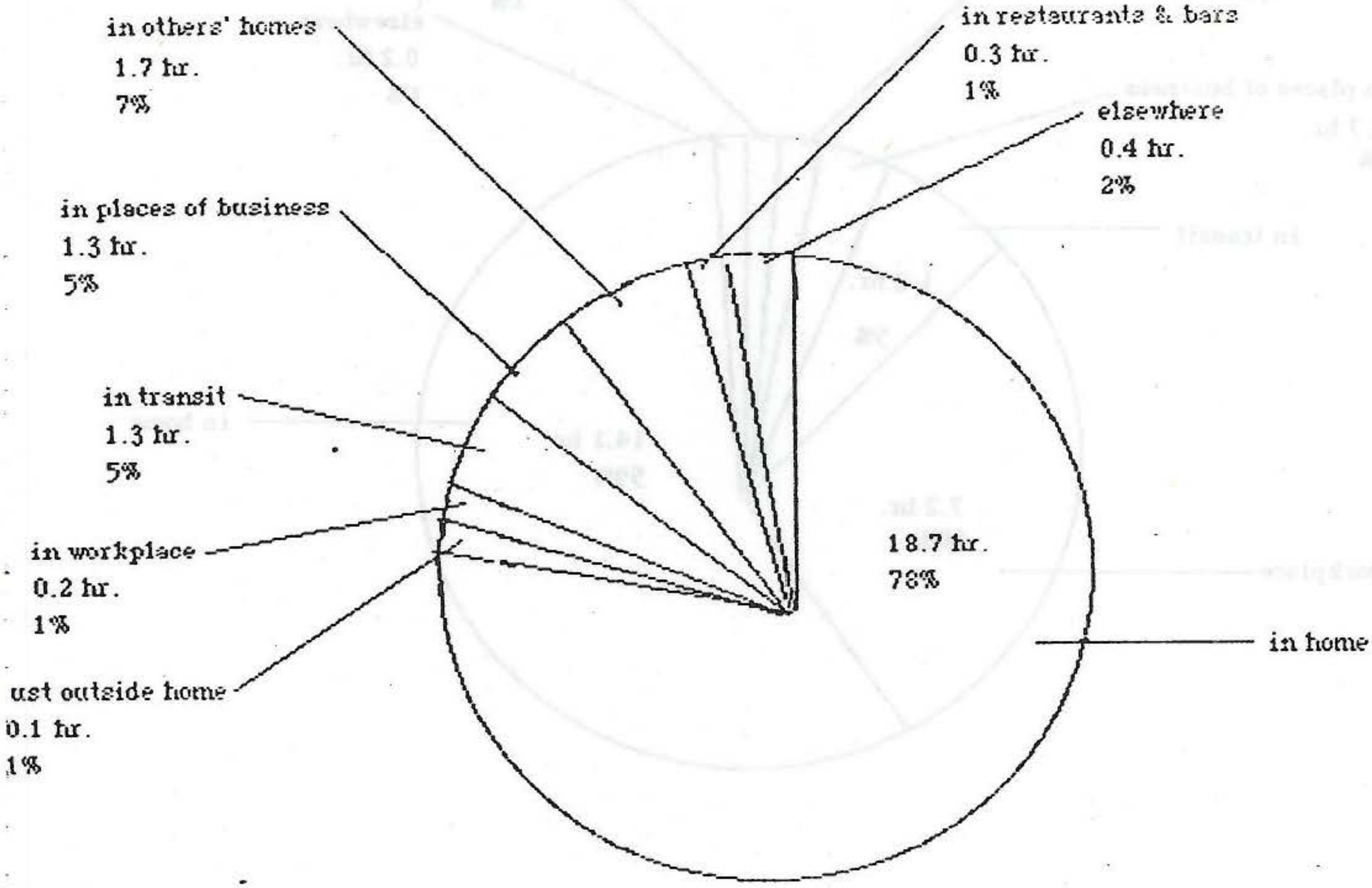
Figure 3-2. Spatial allocation of time: employed males–day off.



Note: Zero time just outside home.

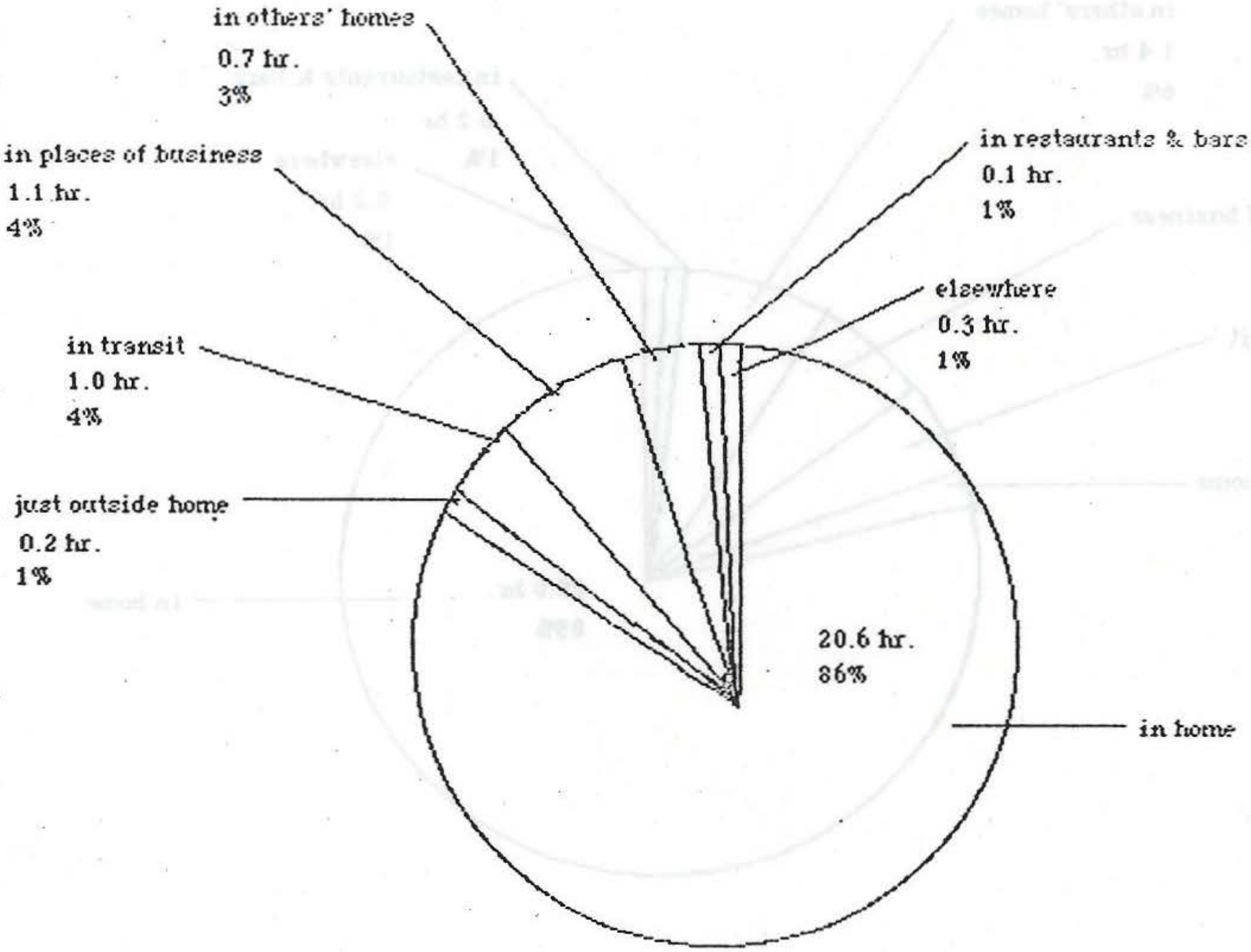
SOURCE: Szalai, Alexander, ed., 1972. The Use of Time. The Hague, Netherlands: Mouton. pp. 795-799.

Figure 3-3. Spatial allocation of time: employed females—workday.



SOURCE: Szalai, Alexander, ed., 1972. The Use of Time. The Hague, Netherlands: Mouton. pp. 795-799.

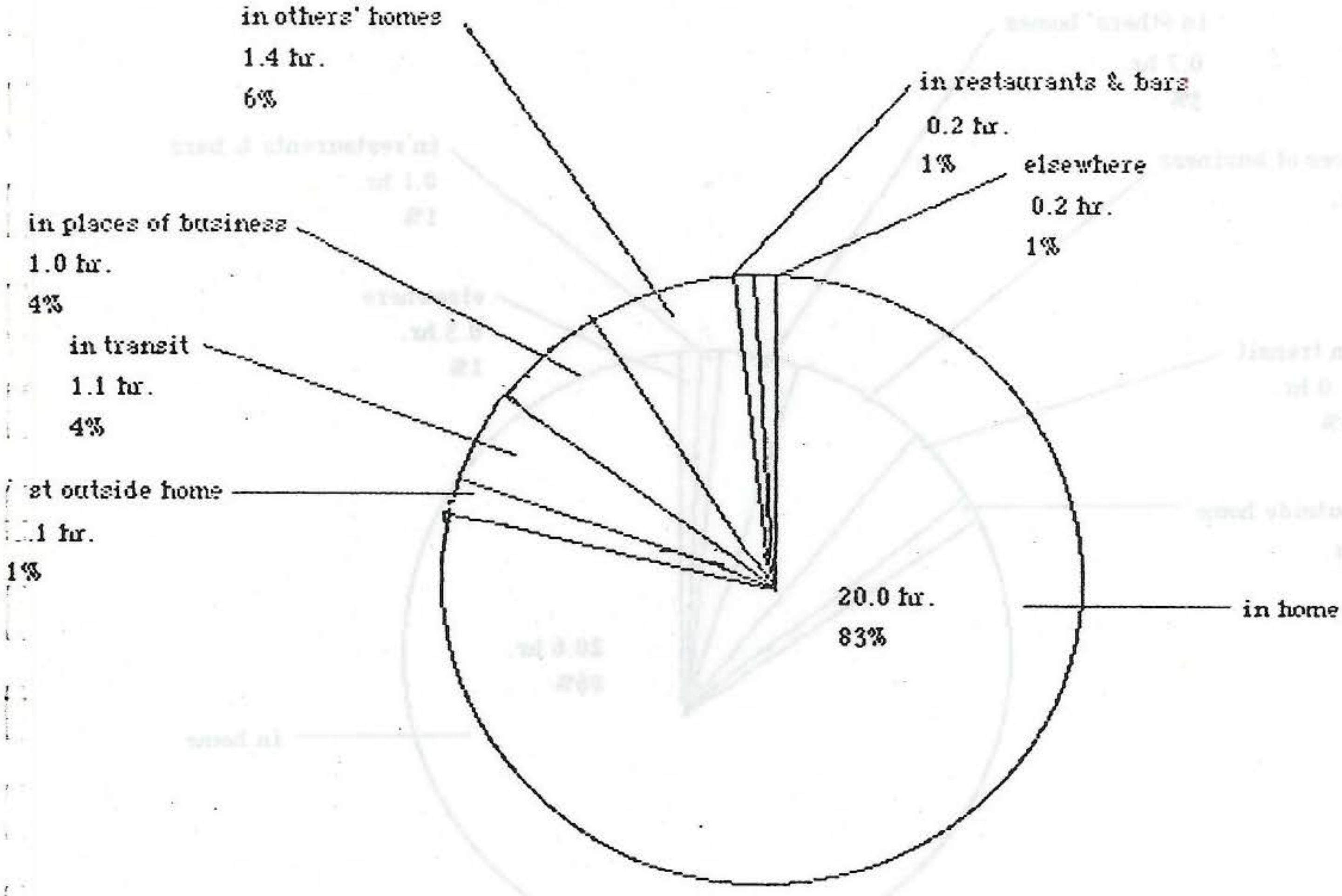
Figure 3-4. Spatial allocation of time: employed females–day off.



Note: Zero time in workplace.

SOURCE: Szalai, Alexander, ed., 1972. The Use of Time. The Hague, Netherlands: Mouton. pp. 795-799.

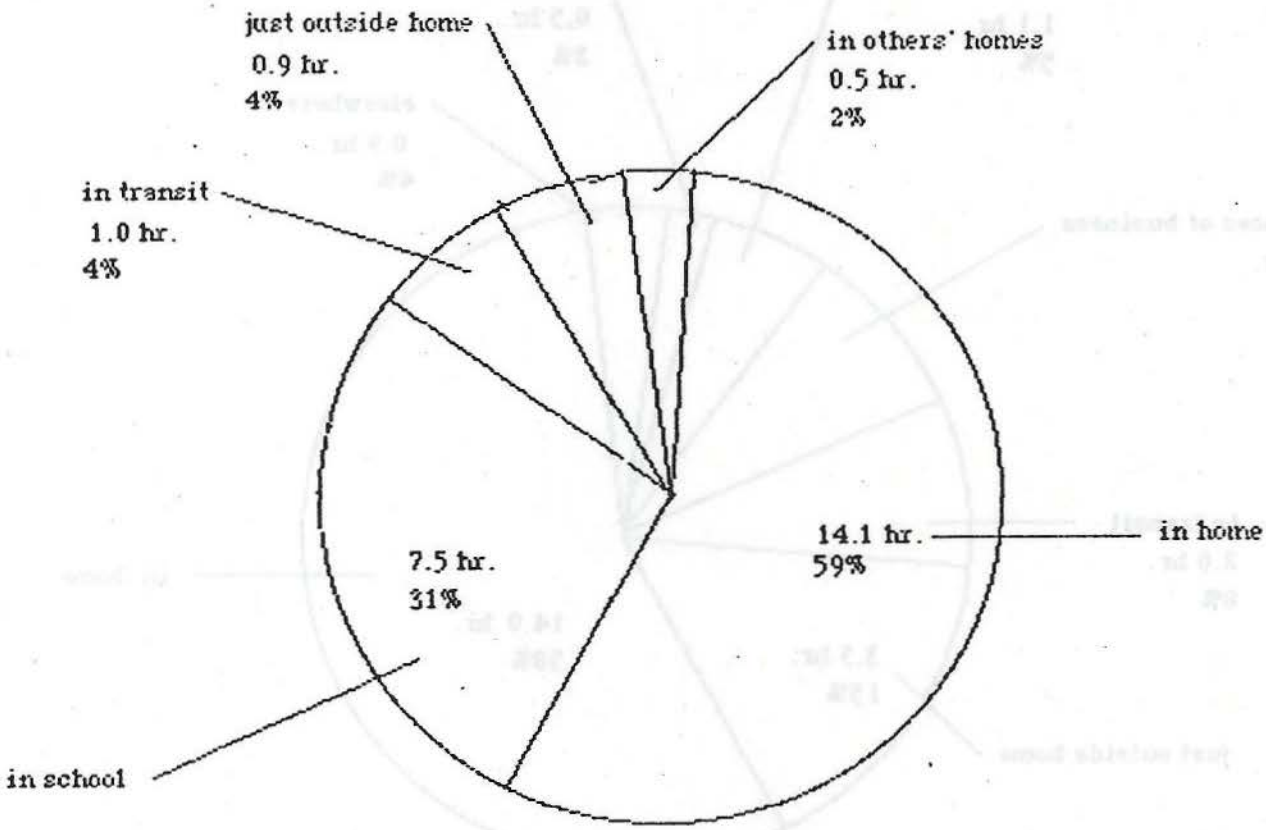
Figure 3-5. Spatial allocation of time: housewives–weekday.



Note: Zero time in workplace.

SOURCE: Szalai, Alexander, ed., 1972. The Use of Time. The Hague, Netherlands: Mouton. pp. 795-799.

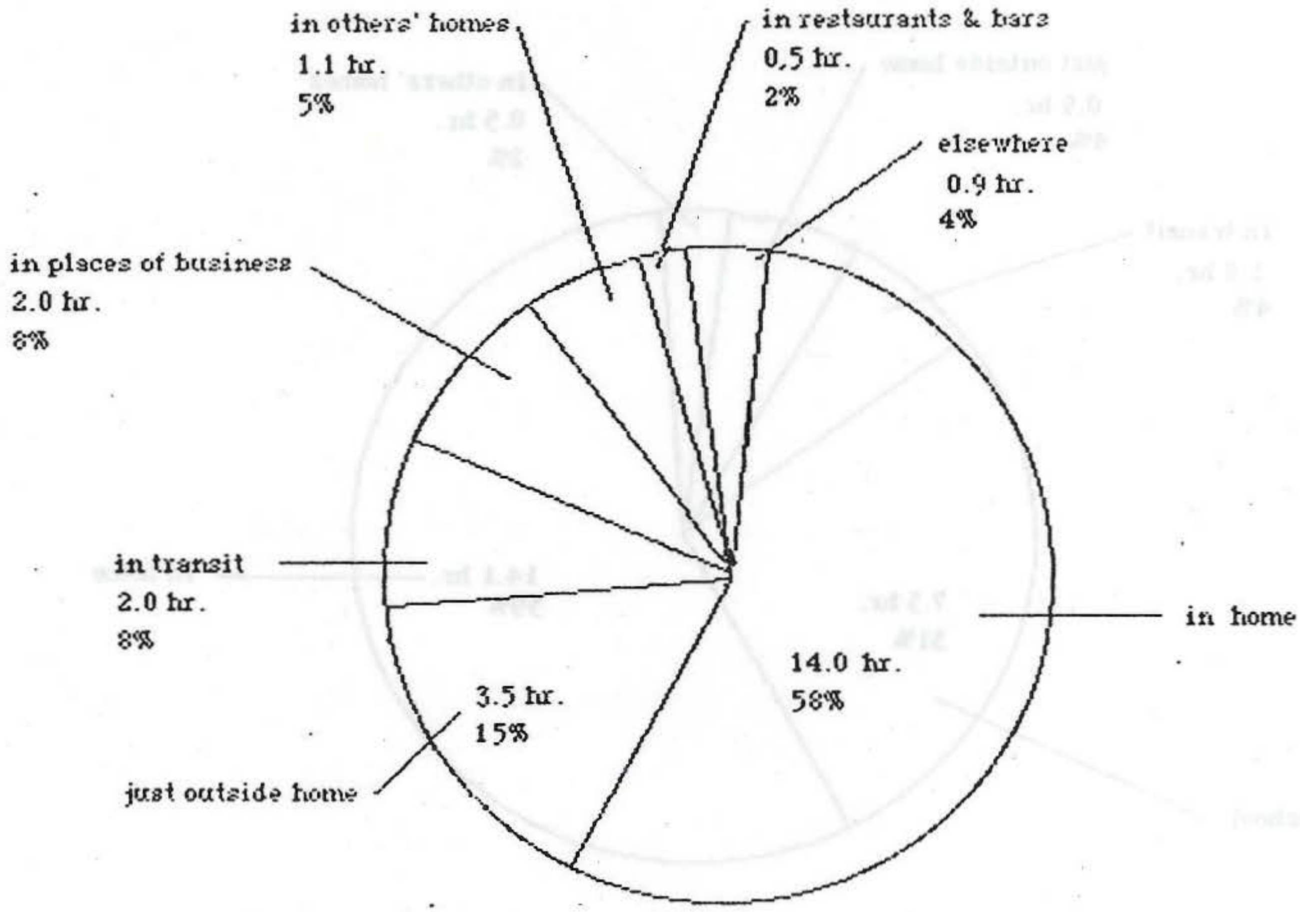
Figure 3-6. Spatial allocation of time: housewives—Sunday.



Note: Zero time in places of business, restaurants and bars, and elsewhere.

SOURCE: Research Triangle Institute estimate.

Figure 3-7. Spatial allocation of time: school age children—school day.



Note: Zero time in school. Includes holidays and summer break.

SOURCE: Research Triangle Institute estimate.

Figure 3-8. Spatial allocation of time: school age children—weekend.

indoors. Other indoor exposures occur in places of business, such as banks, doctors' offices, and stores, in restaurants and bars, in others' homes, and elsewhere. Thus, for most individuals, at least 90 percent of a given day is spent in some indoor environment. For persons whose lifestyle corresponds to that of a housewife, time indoors may account for 95 percent of the time in a day. (Repace, 1982; Spengler and Sexton, 1983; Spengler and Colome, 1982; NRC, 1981b).

The remainder of an individual's day is spent in the ambient environment just outside his or her own home, or elsewhere, or in a transportation microenvironment, such as a bus or automobile, while in transit. These environments expose individuals at different levels than do indoor environments, as outlined in previous subsections.

The study of the division of time among different locations provides a context for more accurately assessing the exposure a population subgroup, or more appropriately, an individual, faces over the course of a day. The next section describes this relationship and provides examples of daily exposure patterns for three subgroups.

3.3 EXPOSURE PROFILES FOR SELECTED POPULATION SUBGROUPS

The emergence of indoor air pollution as a problem separate from outdoor air pollution has enlarged the context for consideration of individual exposure to pollutants. Previously, ambient monitoring data were considered sufficient for calculation of exposure (Repace, 1982; Spengler and Colome, 1982). Much effort in the last ten years has focused on collecting data on the sources and effects of indoor pollutants (Spengler and Sexton, 1983).

Formaldehyde is of particular concern as an indoor pollutant in both the home and the workplace, because of its widespread use in building materials and furnishings present in most homes, and its use in many production processes. The factors already discussed cause wide fluctuation in emission rates and concentrations in the indoor environments.

Even within a structure, levels of formaldehyde vary from room to room, and from hour to hour (Gammage et al., 1983; Hawthorne et al., 1983). As concentrations vary, so will exposures to formaldehyde. A daily exposure profile may be constructed for any individual based on the exposure levels at locations an individual frequents, and the time of day he or she is present at that site, or in that environment. Both hourly exposure profiles and daily time-weighted averages of exposure to formaldehyde are provided below.

3.3.1 Hourly Exposure Profiles

Figures 3-9 through 3-17 provide representations of hourly exposures for sample employed males, employed females, and housewives, for weekdays, Saturdays, and Sundays. On each line chart are graphs which depict different combinations of low exposure jobs (LE job), high exposure jobs (HE job), low exposure homes (LE home), and high exposure homes (HE homes). For housewives, two graphs are shown - low exposure homes (LE home) and high exposure homes (HE home), since this subgroup is presumed not to work outside the home environment.

Data from Szalai (1972) and the ambient and indoor concentration levels presented in Section 3.1 were used to construct these graphs. Activities for each hour were associated with locations, and locations with formaldehyde concentrations. For each hour, average exposure was calculated by multiplying the percentage of the subgroup engaged in different activities and the exposure presumed to be associated with the activities, and summing the results.

The activity categories used by Szalai (1972) and the locations which we associated with them are as follows:

Television viewing	- in home
Other media	- in home
Other leisure	- in restaurants, bars, and places of business
Semi-leisure	- in home
Home and family care	- in home
Traveling	- in transit
Working	- in workplace
Eating	- in home
Sleeping	- in home

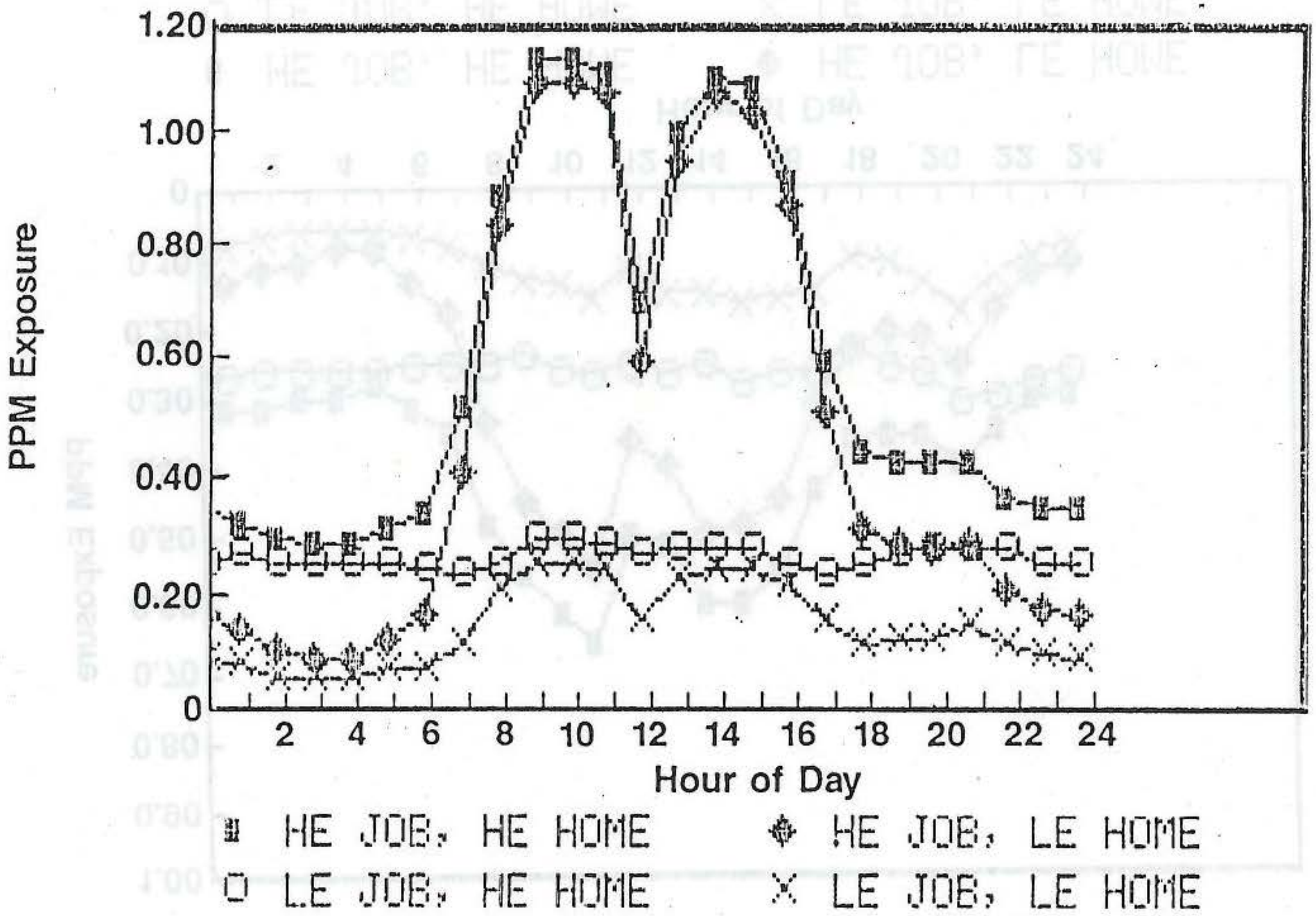


Figure 3-9. Average hourly formaldehyde exposure: employed males—weekday.

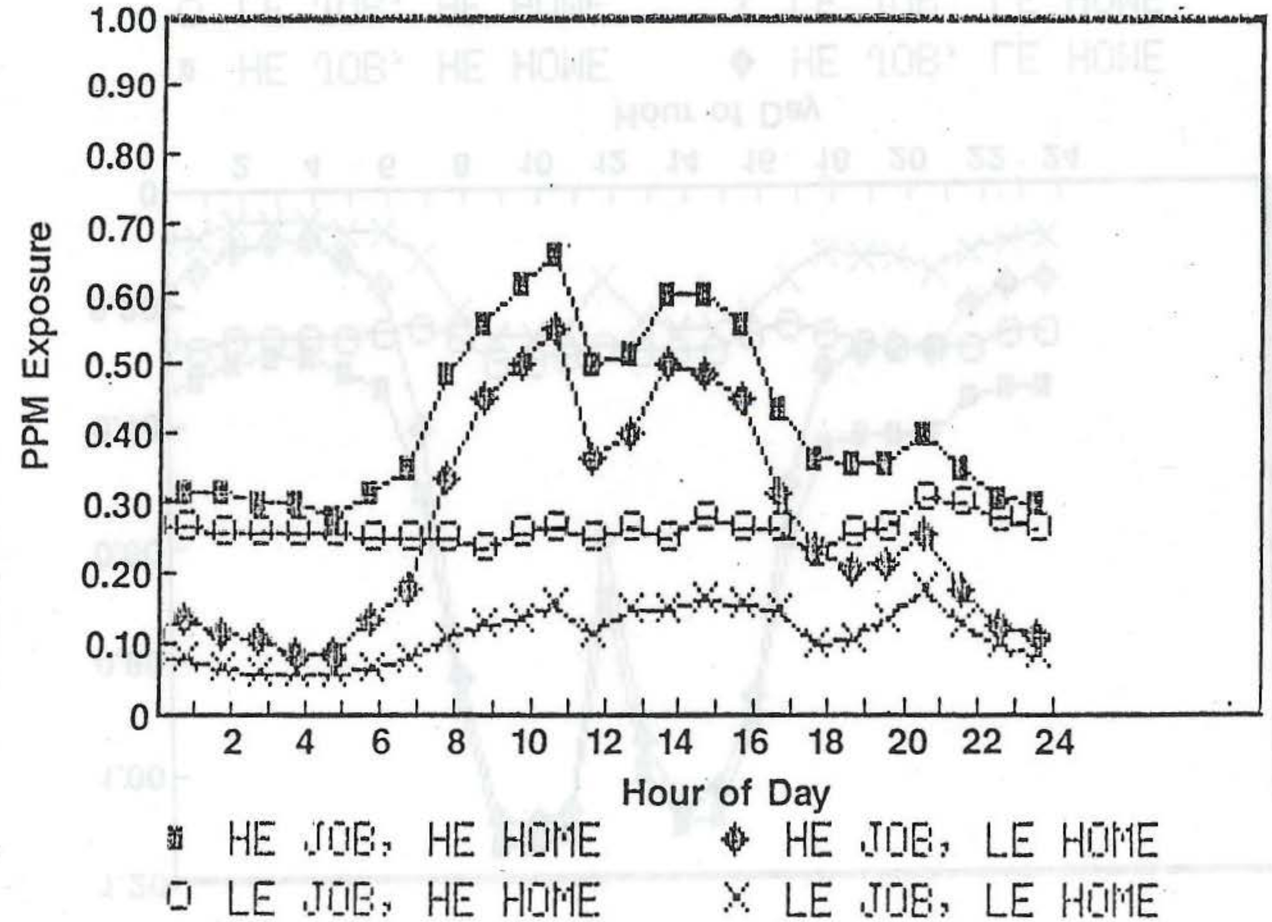


Figure 3-10. Average hourly formaldehyde exposure: employed males—Saturday.

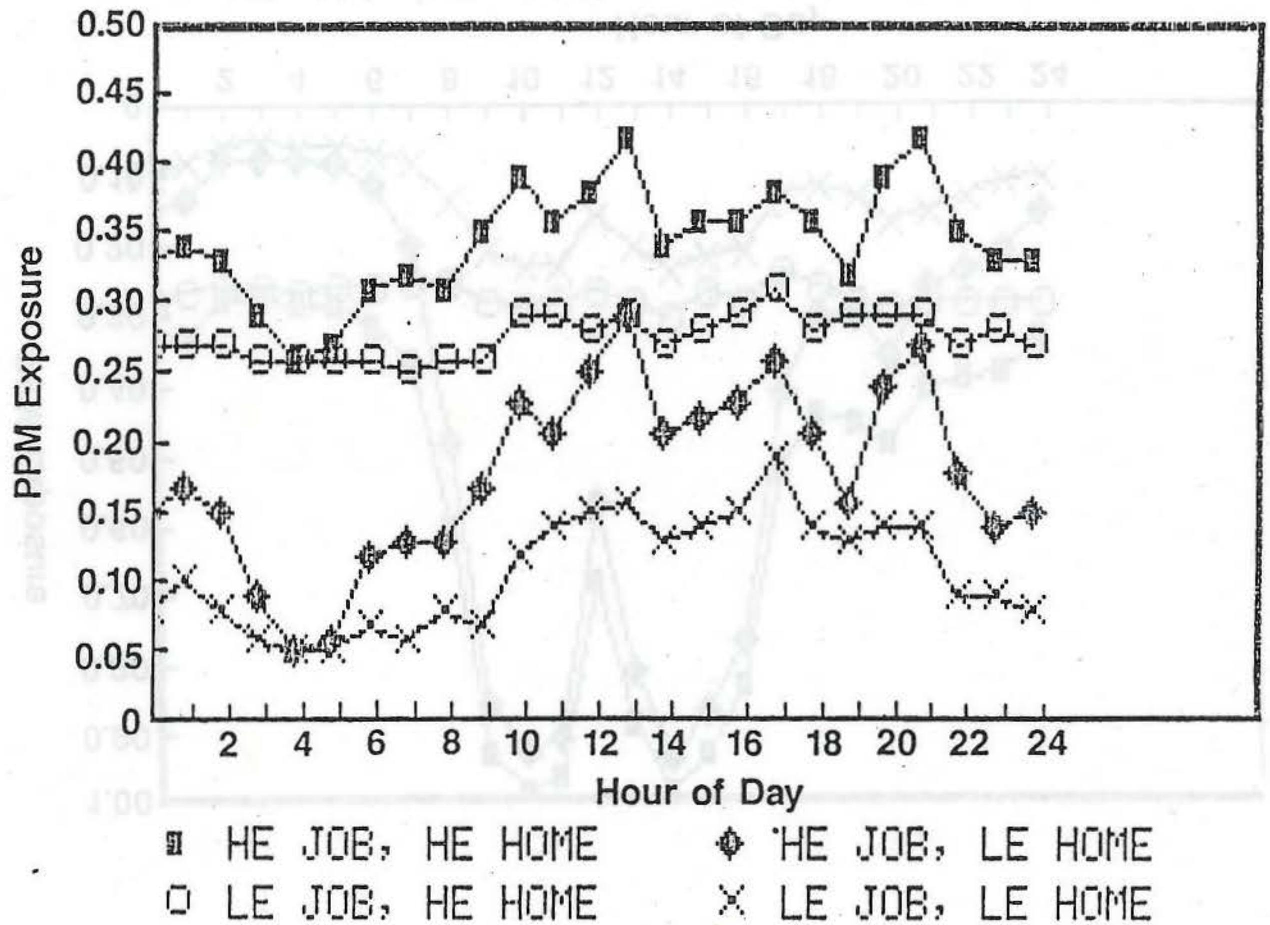


Figure 3-11. Average hourly formaldehyde exposure: employed males—Sunday.

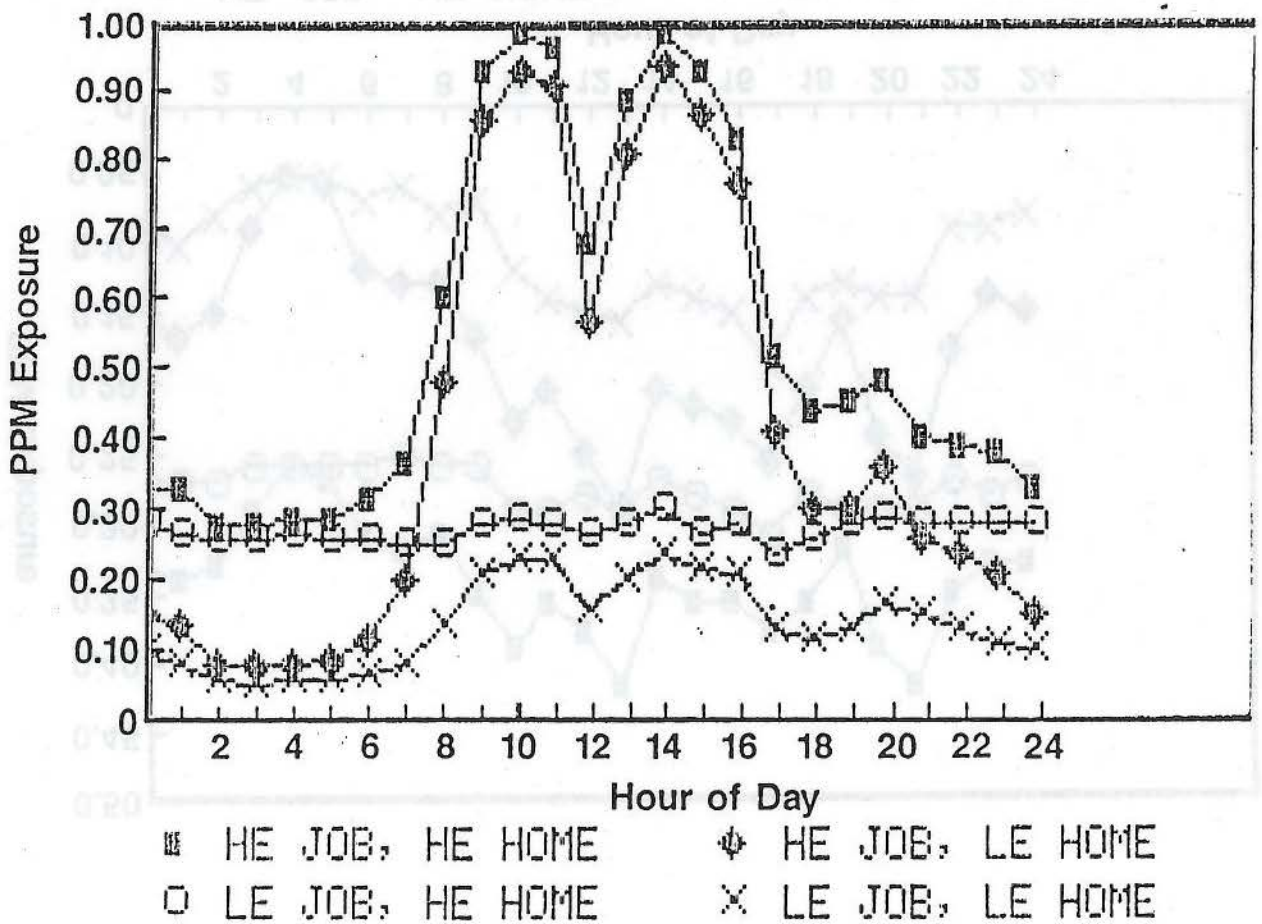


Figure 3-12. Average hourly formaldehyde exposure: employed females—weekday.

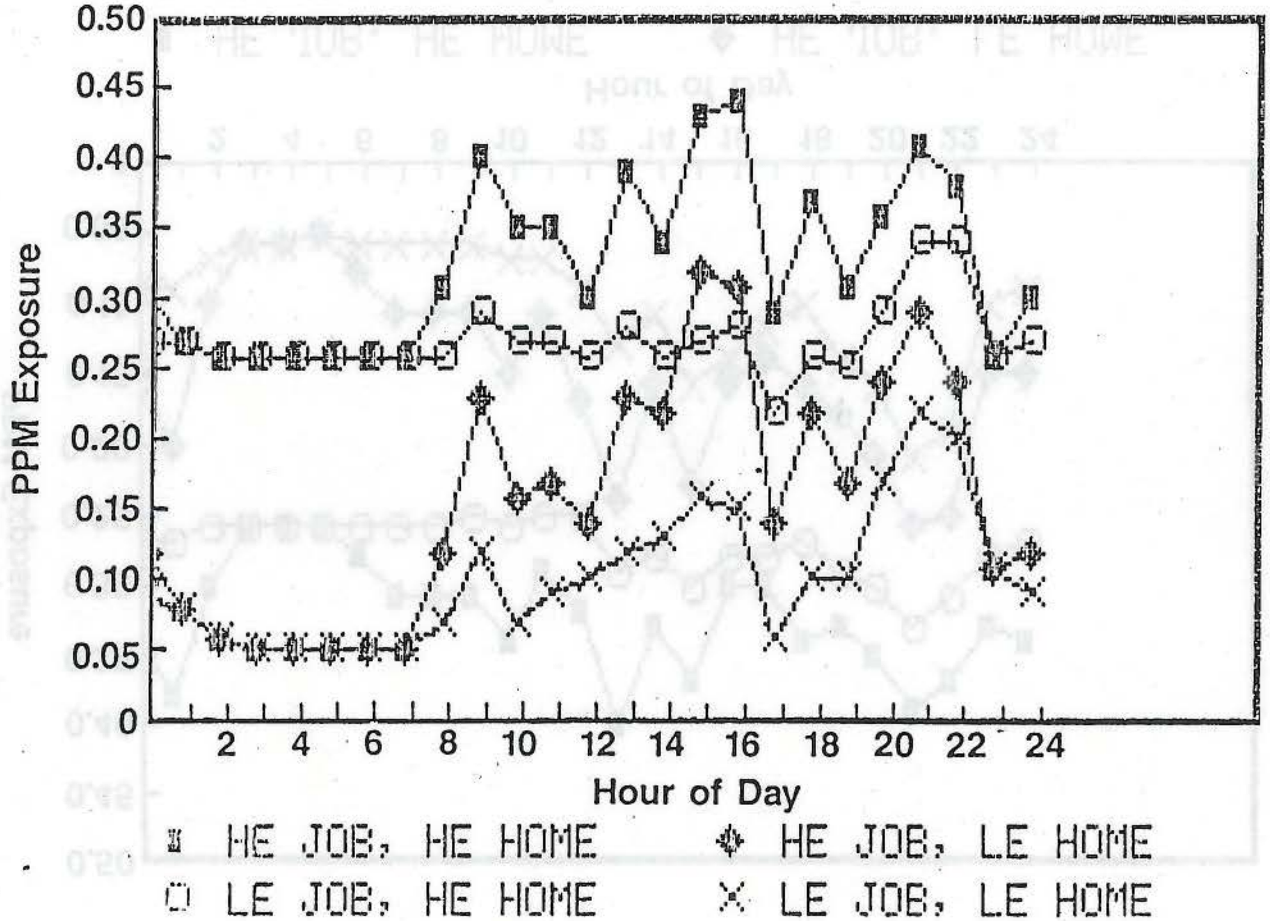


Figure 3-13. Average hourly formaldehyde exposure: employed females—Saturday.

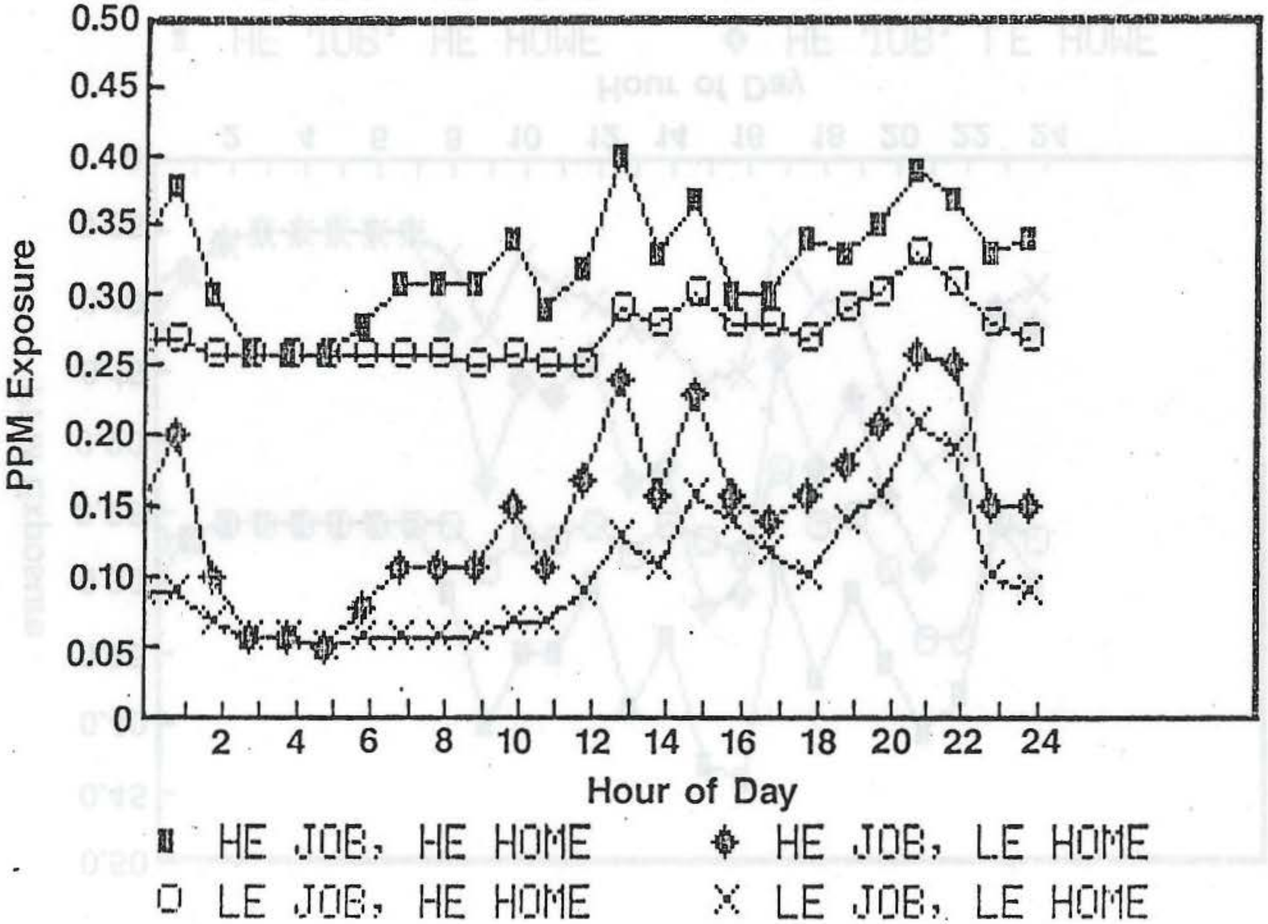


Figure 3-14. Average hourly formaldehyde exposure: employed females—Sunday.

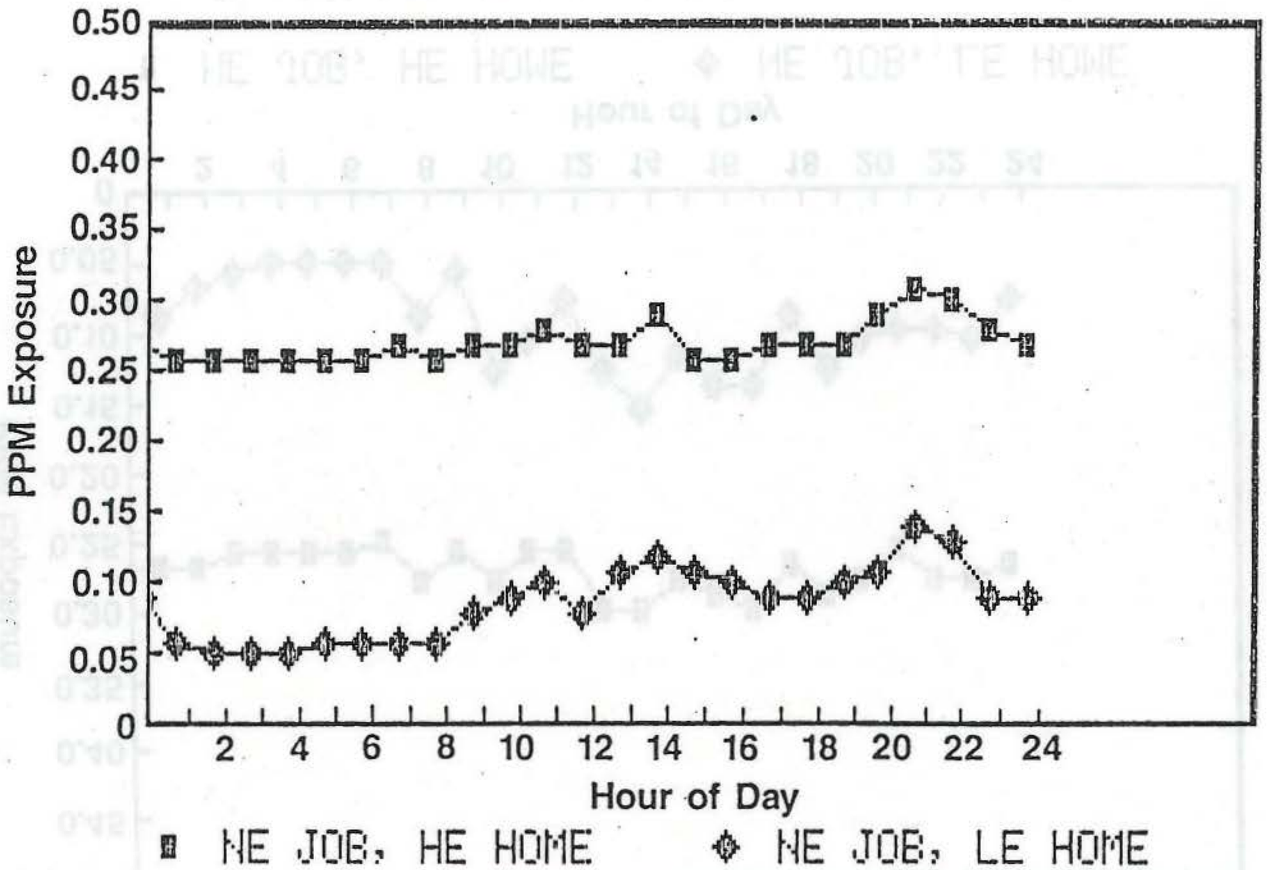


Figure 3-15. Average hourly formaldehyde exposure: housewives–weekday.

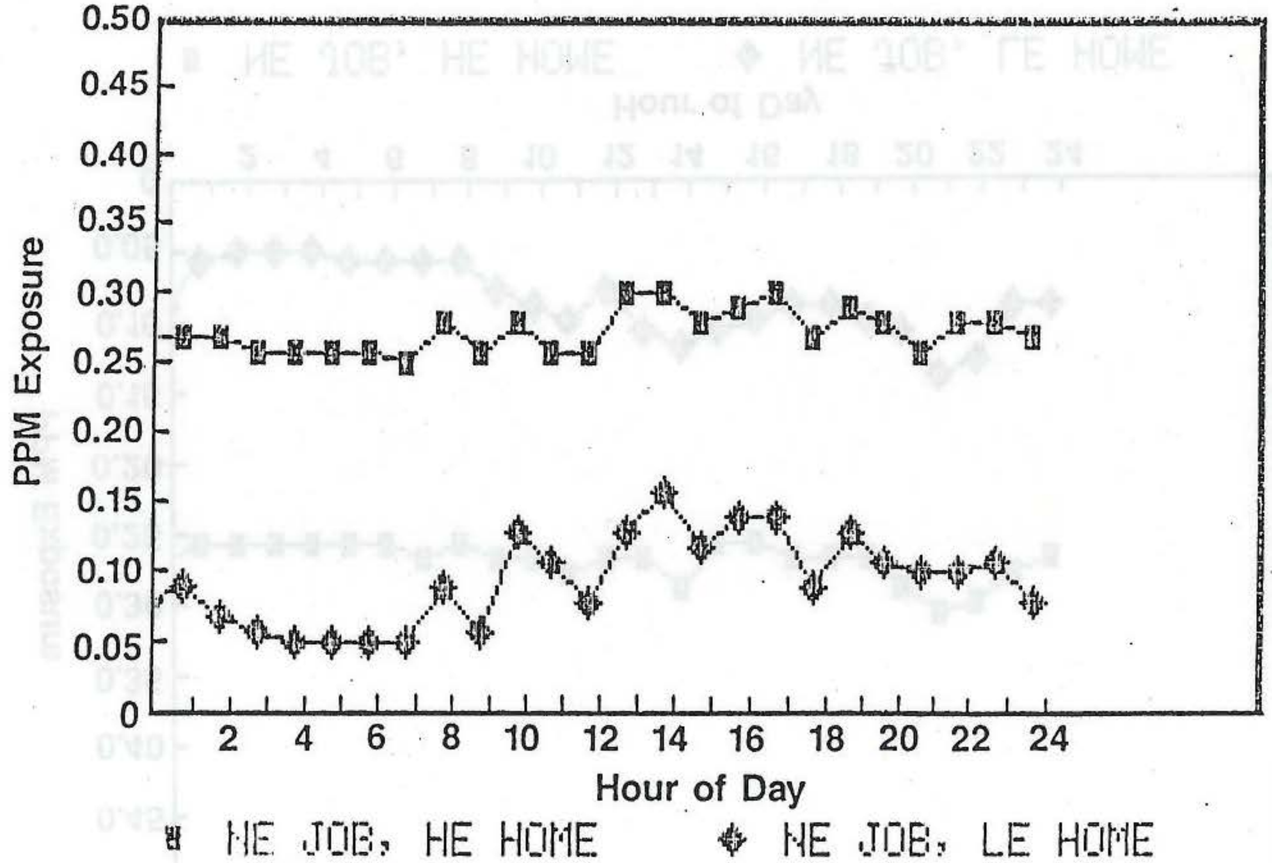


Figure 3-16. Average hourly formaldehyde exposure: housewives—Saturday.

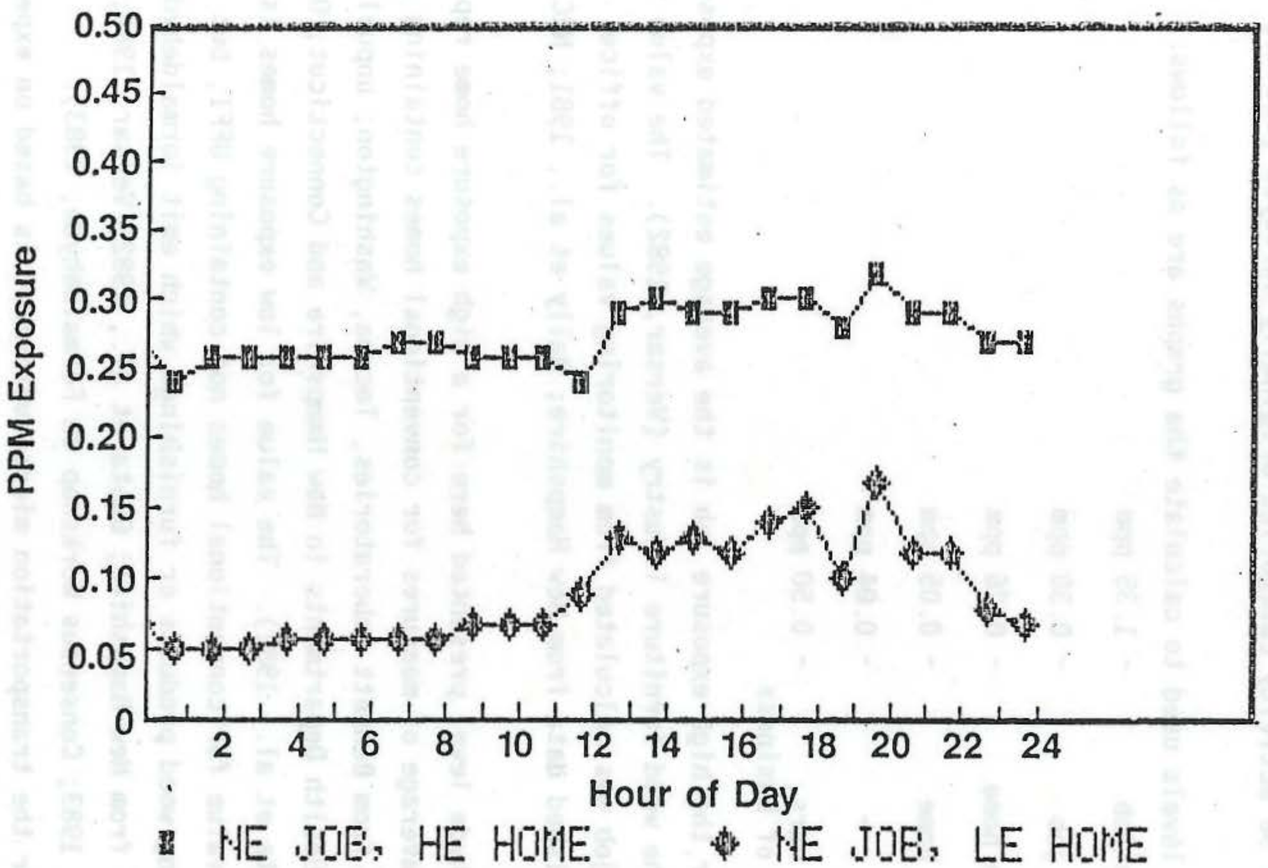


Figure 3-17. Average hourly formaldehyde exposure: housewives—Sunday.

We recognize that these categorizations overgeneralize the locations where each of the activities may be performed. However, this is necessary due to the infeasibility of determining how many persons are in each place when performing each activity. The activity categories themselves are simplifications of 96 activity categories originally surveyed (Szalai, 1972).

The exposure levels used to calculate the graphs are as follows:

High exposure job	- 1.35 ppm
Low exposure job	- 0.30 ppm
High exposure home	- 0.26 ppm
Low exposure home	- 0.05 ppm
In transit	- 0.04 ppm
Restaurants, bars, and places of business	- 0.50 ppm

The value for the high exposure job is the average estimated exposure for a worker in the wood furniture industry (Versar, 1982). The value for the low exposure job was calculated from monitoring values for office buildings (unpublished data from New Hampshire; Dally et al., 1981; NRC, 1981a).

The formaldehyde level presented here for a high exposure home represents a weighted average of measures for conventional homes containing UFFI (unpublished data from Bennett Laboratories, Tacoma, Washington; unpublished data from Public Health Departments in New Hampshire and Connecticut; Dally et al., 1981; Gupta et al., 1982). The value for low exposure homes is a weighted average value for conventional homes not containing UFFI, but possibly containing wood products or furnishings which emit formaldehyde (unpublished data from New Hampshire; Gupta et al., 1982; Versar, 1982; Hawthorne et al., 1983; Consensus Workshop on Formaldehyde, 1983).

The value for the transportation microenvironment is based on expected urban ambient concentrations, under an assumption of traffic conditions conducive to formaldehyde release (NRC, 1981a; Versar, 1982). Actual conditions will vary, but most cities are considered to have ambient levels lower than 0.1 ppm. Levels of 0.04 ppm were found in Wisconsin cities (NRC, 1981a). The selected value may overstate formaldehyde concentrations under many atmospheric conditions, and in many areas.

The value for restaurants, bars, and places of business is based on the assumption that building conditions are exacerbated by possible crowding and by smoking by the persons in the building. This concentration represents an estimation derived from unpublished New Hampshire data, from Wisconsin data (Dally et al., 1981), and from a value estimated for public buildings (NRC, 1981a).

The calculation of twenty-four hour time weighted averages (TWA) requires different values for formaldehyde exposure for some locations. The TWA are primarily based on locations, rather than primarily on activities and only secondarily on the locations of those activities. Exposures used for TWA calculations are as follows:

Just outside home	- 0.01 ppm
In transit	- 0.04 ppm
In places of business	- 0.21 ppm
In others' homes	- 0.05 ppm
In restaurants and bars	- 0.50 ppm
Elsewhere	- 0.01 ppm
In school	- 0.07 ppm
In home	
(high exposure)	- 0.40 ppm
(low exposure)	- 0.05 ppm
In workplace	
(high exposure)	- see Table 3-2
(low exposure)	- 0.05 ppm

Exposures for "in workplace" are obtained from Table 3-2 for particular industries and for low exposure jobs. The exposures for the categories "just outside home" and "elsewhere" are assumed to be in the ambient environment. The value is based on data compiled by the Health Sciences Directorate at the Consumer Products Safety Commission (Gupta et al., 1982). Exposure "in others' homes" is assumed to be at the low exposure concentration, since 98 percent of the homes in the U.S. are in this category (Versar, 1982). The value for "places of business" is based on data for public buildings (NRC, 1981a). The exposure level for "in school" is based on unpublished New Hampshire data. The concentration for high exposure home is the average level for new mobile homes and conventional homes containing UFFI (NRC, 1981a). The values for the categories "in transit," in restaurants and bars," "in home" (at low exposure) have been discussed.

For employed males and employed females, the high exposure job-high exposure home (HE job, HE home) combination exposes the individual to the highest exposures on an hour-by-hour basis, for all days of the week. On weekdays (Figure 3-9 and Figure 3-12), exposure is highest from about 8:00 a.m. to 6:00 p.m., the hours of an average workday, with a sharp decrease in exposure between lunchtime hours (11:00 a.m. to 1:00 p.m.). During this time, males face higher exposures than females because a greater percentage of males are at work during these hours. Males have, on average, longer workdays than females (8.5 hours versus 7.2 hours).

The low exposure job, low exposure home combination (LE job, LE home) and the high exposure job, low exposure home (HE job, LE home) display the same pattern of higher exposure in the workplace, with a decrease at lunchtime. The LE job, LE home graph is significantly lower than the HE job, HE home graph. The HE job, LE home is closely associated with each of these extremes, being similar to LE job, LE home during offwork hours, and similar to HE job, HE home during work hours.

The low exposure job, high exposure home (LE job, HE home) combination displays almost constant exposure throughout the day for weekdays. The exposure level is similar to the LE job, LE home during work hours, and to the HE job, HE home during nonwork hours.

For employed males, exposures on Saturdays (Figure 3-10) are similar to that of weekdays (Figure 3-9), but are at much lower concentrations, due to having a lower percentage of males working on Saturday. For employed females, Saturdays (Figure 3-13) show a greater resemblance to Sundays

(Figure 3-14). In general, these graphs display the effect of more women spending time at home, or in restaurants, bars, and places of business. During the morning hours, employed women tend to spend more time in the home, while at night they spend more time working and going out. Employed males also spend more time at home on Sunday (Figure 3-11), so that the disparity between job and home circumstances is diminished.

Housewives experience very stable patterns of exposure, as would be expected from the amount of time they spend in the home (Figure 3-15, Figure 3-16, and Figure 3-17). The two combinations of relevance are no exposure job, low exposure home (NE job, LE home), and no exposure job, high exposure home (NE job, HE home). The highest exposures of the week for both combinations occur on Sunday evenings, when many housewives are participating in activities outside the home.

These values are relevant only for the circumstances specified, and should not be construed to represent the entire U.S. population. The graphs serve to indicate how individual exposures may be calculated for the hour subdivisions in a day.

It must be noted that these graphs overlook differences between weekdays in time spent at home, at work, and elsewhere. This variation was described by Chapin (1974). Based on a sample of 1667 divided among five days, Chapin (1974, p. 121) reported the following mean hours spent out of home by day of week:

Monday	-	8.48 hours
Tuesday	-	8.17 hours
Wednesday	-	8.80 hours
Thursday	-	7.85 hours
Friday	-	10.65 hours.

Depending on other locations frequented and their exposures, hourly exposure differences between days of week could be significant.

The lack of data for evaluation of hourly exposures is a major obstacle in determining potential risk of acute conditions as a result of formaldehyde. A time budget study which specifies location and formaldehyde exposure for particular times of day would greatly enhance exposure assessments.

3.3.2 Average Daily Exposures

Daily exposure to indoor pollutants consists of the sum of exposures received in different locations, weighted by the amount ot time spent in each of those locations (Spengler and Colome, 1982). For many pollutants, even if indoor concentrations are low, they may make a substantial contribution to a time-weighted average exposure (Spengler and Sexton, 1983).

The concept of a time-weighted average (TWA) exposure is well-known in occupational settings. Standards are often set based on permissible eight-hour maximum or average concentrations of a pollutant. In the case of formaldehyde, which is predominantly generated in indoor environments, a useful measure of exposure is a TWA based on a twenty-four hour period. As indicated in Section 3.3.1, total exposures to formaldehyde vary depending on all the indoor environments an individual encounters, rather than only the occupational setting.

Table 3-6 shows the average daily exposures, based on a twenty-four hour TWA, associated with the three population subgroups and four exposure combinations described in Section 3.3.1. The most prominent conclusion from this table is that the workplace may contribute a substantial amount to average daily exposure. On workdays, this factor overrides the exposure in homes in importance. On days off, the exposure levels found in the homes assume greater significance because the amount of time spent in the home increases by 40 percent for employed males and by 30 percent for employed females (see Figures 3-1 through 3-4).

3.4 ESTIMATES OF THE POPULATION EXPOSED TO FORMALDEHYDE

Any estimates of time-weighted average or cumulative exposures to formaldehyde for the entire U.S. population are bound to oversimplify the actual circumstances, given presently available data. As the preceding sections demonstrate, individual exposure is a function of lifestyle and of the environments in which the individual spends his or her time. Even at the level of population subgroups, substantial simplifications must be made.

We have attempted to categorize persons in the U.S. population in terms of the potential risk groups outlined in Chapter 2. Table 3-7 shows the distribution of the U.S. population among these classes.

TABLE 3-7 (continued)

[a]Estimates assume no self-selection among persons with chronic respiratory conditions with regard to type of home or participation in labor force. Zero may be regarded as a lower bound on estimates of persons in high exposure homes with chronic respiratory conditions with complete self-selection, since potentially no one with such a condition would choose to live in a high exposure environment, or work in a high exposure occupation.

[b]Type of home is based on Versar, Inc. (1982). The HE home category includes conventional homes containing UFFI and new mobile homes, as defined by Versar, Inc. (1982). The LE home category includes all homes not included in the HE category.

[c]Total population values derived from Statistical Abstract of the United States, 1982-83.

[d]Chronic respiratory conditions include upper and lower respiratory conditions. Data derived from National Medical Care Utilization and Expenditure Survey (1980).

[e]Total United States labor force, including Armed Forces.

SOURCES: 1. Bureau of Census, 1982. Statistical Abstract of the United States, 1982-83. 103rd edition. Washington, D.C.: U. S. Department of Commerce. pp. 30, 376, 379.

2. Research Triangle Institute, 1980. National Medical Care Utilizations and Expenditures Survey (NMCUES). Survey sponsored by the National Center for Health Statistics and the Health Care Financing Administration. Unpublished data.

3. Versar, Inc. 1982. Exposure Assessment for Formaldehyde. Contract No. 68-01-6271. Prepared for Office of Toxic Substances, Environmental Protection Agency. Springfield, Virginia. p. 112.

The National Research Council (1981a) has estimated that from 10 percent to 20 percent of the U.S. population may be susceptible to formaldehyde. Subgroups which are at highest risk include persons with hyperreactive airways, some atopic persons, some nonatopic persons, and some "normal" individuals (NRC, 1981a). Added to these categories may be the elderly, the infirm, and the very young, who are highly susceptible to many types of air pollution, and who may spend all or most of their time indoors (Yocom, 1982). Children may be at elevated risk because their breathing rates, which determine exposure by inhalation, are higher than are those of adults (Consensus Workshop on Formaldehyde, 1983).

Besides inherently high risk subgroups, high exposure homes and occupations may contribute to adverse effects merely by providing an environment in which continual exposure occurs. Although one might not expect high risk populations to intentionally place themselves in a high exposure environment, those persons who do not immediately experience problems with formaldehyde may maintain lifestyles (jobs and homes) which expose them at levels which eventually adversely affect their health.

We assume proportional distribution among the categories in Table 3-7. Although self-selection undoubtly occurs, the lack of data leads us to assume no self-selection in this analysis.

Adults in the labor force are assumed to be divided among those occupations causing elevated exposures to formaldehyde (see Table 3-8) and other occupations. As the Consensus Workshop on Formaldehyde (1983) pointed out, U.S. industries have not been thoroughly evaluated as to the concentrations of formaldehyde to which individual workers are exposed. We use data from Versar (1982), but do not suggest that it is fully representative of the entire U.S. labor force. For this study, we assume that workers excluded from the Versar categories are in low exposure occupations.

Based on the data in Table 3-7, approximately two percent of the U.S. population live in a high exposure environment, defined as either a new mobile home, or a conventional home containing UFFI. The average exposure for this category is 0.40 ppm (NRC, 1981a). The remainder live in low exposure homes at 0.05 ppm (Consensus Workshop on Formaldehyde, 1983).

TABLE 3-6. AVERAGE DAILY EXPOSURES FOR FOUR CASES (ppm)[a]

Employment/ gender/day	HE Job HE Home	HE Job LE Home	LE Job HE Home	LE Job LE Home
Employed male				
Workday	0.64	0.52	0.27	0.16
Day off	0.26	0.11	0.25	0.10
Employed female				
Workday	0.58	0.46	0.27	0.14
Day off	0.27	0.10	0.26	0.09
Housewife[b]	HE Home	LE Home		
Weekday	0.27	0.08		
Sunday	0.26	0.08		

[a]HE represents "high exposure"; LE represents "low exposure". HE job is associated with exposure at 1.35 ppm. LE job is associated with exposure at 0.30 ppm. HE home is associated with exposure at 0.26 ppm. LE home is associated with exposure at 0.05 ppm.

[b]Housewives are assumed not to hold jobs which require them to travel to a specified workplace and to perform the job at that location. The combinations involving LE jobs and HE jobs do not apply for this category.

TABLE 3-7. ESTIMATED NUMBER OF PERSONS EXPOSED TO FORMALDEHYDE BY AGE, HEALTH, LABOR FORCE PARTICIPATION, AND TYPE OF HOME (ASSUMING NO SELF SELECTION[a]) (10^3)

Age/health/labor force participation category	Type of home[b] High exposure (HE)	Low exposure (LE)	Totals[c]
Infants and young children (< 6 years old)	387.8	16,551.2	16,939.0
Chronic respiratory[d]	114.3	4,876.3	4,990.6
No chronic respiratory	273.5	11,674.9	11,948.4
School age children (6 - 15 years old)	573.6	24,479.4	25,053.0
Chronic respiratory	187.6	8,008.1	8,195.7
No chronic respiratory	386.0	16,471.3	16,857.3
Adults not in labor force (16 - 64 years old)	1,219.0	52,023.0	53,242.0
Chronic respiratory	160.6	6,851.3	7,011.9
No chronic respiratory	1,058.4	45,171.7	46,230.1
Elderly not in labor force (65 + years old)	532.6	22,728.4	23,261.0
Chronic respiratory	87.3	3,729.4	3,816.7
No chronic respiratory	445.3	18,999.0	19,444.3
Adults in labor force[e] (16 + years old)	2,537.0	108,275.0	110,812.0
Chronic respiratory	341.2	14,558.8	14,900.0
No chronic respiratory	2,195.8	93,716.2	95,912.0
Male	1,463.8	62,474.7	63,938.5
Chronic respiratory	196.9	8,400.4	8,597.3
No chronic respiratory	1,266.9	54,074.3	55,341.2
Female	1,073.2	45,800.3	46,873.5
Chronic respiratory	144.3	6,158.4	6,302.7
No chronic respiratory	928.9	39,641.9	40,570.8
All age, health, and labor force categories	5,250.0	224,057.0	229,307.0

See footnotes on following page.

The data in Tables 3-7 and 3-8 indicate that approximately 1.7 percent of the U.S. labor force works in high exposure jobs. The exposures vary depending on the industry (Versar, 1982). Those labor force participants employed in low exposure jobs are assumed to work at concentrations of 0.05 ppm, the minimum reported threshold for odor and neurophysiologic effects (NRC, 1981a). For perhaps many persons in this group, formaldehyde levels will exceed this concentration due to exposure in offices containing furnishings with high emission rates. The separation of this subgroup is not attempted in this report.

We may assign the population estimates in Table 3-7 to categories similar to those in Section 3.3.2 as follows:

HE job, HE home	-	43,000
HE job, LE home	-	1,820,000
LE job, HE home	-	2,495,000
LE job, LE home	-	106,454,000
No job, HE home	-	2,712,000
No job, LE home	-	115,783,000

These numbers represent 0.02 percent, 0.79 percent, 1.09 percent, 46.42 percent, 1.18 percent, and 50.49 percent of the U.S. population, respectively. The exposure patterns represented in Figures 3-9 through 3-17 roughly represent the relative hour-by-hour exposures for different days of the week for these percentages of the population.

These are only approximate values, however, because some persons not in the labor force are exposed to formaldehyde at elevated levels for at least a portion of the day. These are mainly high school and university biology students, medical, dental and nursing students (Versar, 1982). School age children may also be exposed to formaldehyde in schools at different levels than at home. Additionally, more or less homes than estimated may be regarded as subjecting the occupants to elevated formaldehyde exposures.

A twenty-four hour TWA exposure is calculated for each of the age and employment subgroups. The results are shown in Table 3-9 and Table 3-10.

TABLE 3-8. OCCUPATIONAL EXPOSURES TO FORMALDEHYDE

Industry	Number of persons exposed[a] Men	Women	Total
Formaldehyde manufacturing	1,170	230	1,400
Urea, phenol, melamine and acetal formaldehyde resin manufacturing	5,145	880	6,025
Hardwood plywood manufacturing	5,293	1,407	6,700
Particleboard manufacturing	2,968	1,032	4,000
Wood furniture manufacturing	39,471	19,529	59,000
Mobile home manufacturing	27,500	4,000	31,500
Urea formaldehyde foam chemicals manufacturing	30	20	< 50
Urea formaldehyde foam insulation installation	914	86	< 1,000
Metal molds and castings manufacturing	54,600	5,400	60,000
Plastic products manufacturing	9,912	6,663	16,575
Paper and paperboard manufacturing	7,463	2,667	> 9,730
Textiles manufacturing	12,389	5,411	17,800
Apparel manufacturing	149,961	627,039	777,000
Apparel wholesaling	33,864	32,536	66,400
Building paper and board manufacturing	2,915	885	3,800
Paints and coatings manufacturing	18,538	4,462	23,000
Abrasive products manufacturing	5,467	1,633	7,100
Asbestos products manufacturing	2,695	805	3,500
Urea formaldehyde concentrates manufacturing	33	7	40
Nitrogenous fertilizer manufacturing	1,991	234	2,225[b]
Other large volume formaldehyde derivatives manufacturing	176	34	> 210

(continued)

TABLE 3-8 (continued)

Industry	Number of persons exposed[a] Men	Women	Total
Poultry egg producing and hatching	c	c	1,300
Mushroom farm operation	c	c	1,400
Disinfecting and cleaning service contracting	unknown	unknown	unknown
Service work in health-related facilities	unknown	unknown	unknown
Medical and pathology laboratory work	23,945	31,355	55,300
Dental laboratory work	15,415	20,185	35,600
High school biology teachers	14,012	24,588	38,600
High school biology students	c	c	3,834,000
College and university biology teachers	56,798	51,802	108,600
College and university biology students, medical students, nursing students, and dental students	c	c	3,244,400
Funeral service work	40,095	14,905	55,000
Metalwork machine operation	394,800	75,200	470,000[d]
Total Occupational Exposures (excluding student exposures)	c	c	1,862,855

[a]Estimates of number of men and women exposed to formaldehyde were made based on Bureau of Labor statistics of percentage of women in industries by SIC, assuming that women are proportionally represented in the exposed occupations.

[b]Total number of persons exposed is midpoint of the range 1,600 to 2,850 given by Versar, Inc. (1982) for this industry.

[c]No estimates were made of numbers of men and women exposed to formaldehyde for this industry.

[d]Lower bound given by Versar, Inc. (1982).

SOURCES:
1. Oatway, Janet, and Hans A. Klemm, 1981. Formaldehyde Regulatory Control Options Analysis. Draft Final Report. Contract No. 68-01-5960. Prepared for Office of Chemical Control, Environmental Protection agency. Report No. GCA-TR-81-1-G. Bedford, Massachusetts: GCA Corporation.
2. Versar, Inc., 1982. Exposure Assessment for Formaldehyde. Final Draft Report. Contract No. 68-01-6271. Prepared for Office of Toxic Substances, Environmental Protection Agency. Springfield, Virginia: Versar, Inc. pp. 67-69.

This average is the sum of the multiplications of exposure in a location and the percentage of the day spent in that location, for all locations. Figures 3-1 through 3-8 were used for percentage of time in location. Previously cited concentrations are used for exposure levels.

Table 3-9 reports twenty-four hour TWA exposures for persons not in the labor force. The majority of these subgroups are assumed to have lifestyles similar to that of the housewife subgroup in Figures 3-5 and 3-6. Average exposures for the infants and young children, adults not in the labor force, and elderly not in the labor force in the HE home category are not very different from the segment of the student population who are exposed to formaldehyde in a laboratory setting at high levels (5.2 ppm). These same subgroups are exposed at much lower levels on weekdays in LE homes than are the students. School age children appear to have the lowest daily exposures to formaldehyde for all categories except LE homes on Sunday.

Table 3-10 gives twenty-four hour TWA exposures for persons in the labor force, segregated by male and female workers. The highest exposures occur for workers with HE homes and employment in formaldehyde resin manufacturing, particleboard manufacturing, wood furniture manufacturing, building paper and board manufacturing, abrasive products manufacturing, asbestos manufacturing, and college and university biology teaching.

For most occupations with exposure assumed to occur throughout the workday, there appears to be a concentration level near 0.52 ppm above which males in HE homes experience greater TWA exposures than females in the same occupational and domestic status. For industries with hourly exposures below this level, females in HE homes have slightly higher TWA exposures.

There is some difference among workers of the same gender and occupational category who live in HE homes versus those who live in LE homes. Time-weighted average exposure for LE homes is between 40 and 75 percent of the TWA for HE homes for the same occupational category and gender.

Cumulative individual annual exposures for all subgroups are provided in Tables 3-11 and 3-12. For employed males, employed females, and the student subgroup assumed to have time allocation similar to employed males,

TABLE 3-9. TWENTY-FOUR HOUR TIME WEIGHTED AVERAGE (TWA) EXPOSURE TO FORMALDEHYDE, PERSONS NOT IN LABOR FORCE (ppm)

Age category	HE home[a]		LE home[b]	
	Weekday	Sunday	Weekday	Sunday
Infants and young children[c] (< 6 years old)	0.36	0.35	0.06	0.06
School age children[d] (6 - 15 years old)	0.26	0.27	0.05	0.07
Adults not in labor force[c] (16 - 64 years old)	0.36	0.35	0.06	0.06
Elderly not in labor force[c] (65 + years old)	0.36	0.35	0.06	0.06
College and university biology students, medical students, nursing students, and dental students[e]	0.45	0.32	0.27	0.07

[a]HE home represents high exposure home, with formaldehyde levels assumed to be 0.40 ppm.

[b]LE home represents low exposure home, with formaldehyde levels assumed to be 0.05 ppm.

[c]Daily time allocation assumed similar to that of housewives (see Figures 3-5 and 3-6).

[d]Daily time allocation for school age children is assumed to be as described in text (see Figures 3-7 and 3-8).

[e]Daily time allocation assumed similar to that of employed males (see Figures 3-1 and 3-2). Exposure at levels given in Table 3-4 for five hours per day. Remaining portion of time "in workplace" is assumed to be at formaldehyde levels 0.05 ppm.

TABLE 3-10. TWENTY-FOUR HOUR TIME WEIGHTED AVERAGE (TWA) EXPOSURE TO FORMALDEHYDE, PERSONS IN LABOR FORCE (ppm)

	Male				Female			
	HE home[a]		LE home[b]		HE home[a]		LE home[b]	
Industry	Weekday	Day off	Weekday	Day off	Weekday	Day off	Weekday	Day off
Formaldehyde manufacturing	0.38	0.32	0.20	0.07	0.39	0.34	0.18	0.06
Formaldehyde resin manufacturing[c]	0.71	0.33	0.53	0.08	0.67	0.35	0.46	0.07
Hardwood plywood manufacturing	0.46	0.32	0.28	0.07	0.45	0.34	0.25	0.07
Particleboard manufacturing	0.62	0.33	0.45	0.08	0.59	0.34	0.39	0.07
Wood furniture manufacturing	0.68	0.33	0.50	0.08	0.64	0.35	0.43	0.07
Mobile home manufacturing	0.36	0.32	0.18	0.07	0.37	0.34	0.16	0.06
UFF chemicals manufacturing[d]	0.39	0.32	0.21	0.07	0.40	0.34	0.19	0.07
UFFI installation	0.40	0.32	0.23	0.07	0.41	0.34	0.20	0.07
Metal molds and castings manufacturing	0.34	0.32	0.16	0.07	0.35	0.34	0.14	0.06
Plastic products manufacturing	0.31	0.32	0.13	0.07	0.33	0.34	0.12	0.06
Paper/paperboard manufacturing	0.27	0.32	0.10	0.07	0.29	0.33	0.09	0.06
Textiles manufacturing	0.37	0.32	0.19	0.07	0.38	0.34	0.17	0.06
Apparel manufacturing	0.45	0.32	0.27	0.07	0.44	0.34	0.24	0.07
Apparel wholesaling	0.35	0.32	0.18	0.07	0.36	0.34	0.16	0.06
Building paper and board manufacturing	0.62	0.33	0.45	0.08	0.59	0.34	0.39	0.07
Paints/coatings manufacturing	0.26	0.32	0.09	0.07	0.29	0.33	0.08	0.06
Abrasive products manufacturing	0.61	0.33	0.43	0.08	0.58	0.34	0.37	0.07
Asbestos products manufacturing	0.61	0.33	0.43	0.08	0.58	0.34	0.37	0.07
UF concentrates manufacturing[e]	0.38	0.32	0.20	0.07	0.39	0.34	0.18	0.06

(continued)

TABLE 3-10 (continued)

	Male				Female			
	HE home[a]		LE home[b]		HE home[a]		LE home[b]	
Industry	Weekday	Day off	Weekday	Day off	Weekday	Day off	Weekday	Day off
Nitrogenous fertilizer manufacturing	0.52	0.33	0.34	0.07	0.50	0.34	0.30	0.07
Other large volumes formaldehyde derivatives manufacturing	0.38	0.32	0.20	0.07	0.39	0.34	0.18	0.06
Poultry egg producing and hatching[f]	0.26	0.32	0.08	0.07	0.28	0.32	0.07	0.06
Mushroom farm operation[g]	0.27	0.32	0.10	0.07	0.30	0.32	0.09	0.06
Medical/pathology laboratory work	0.52	0.33	0.34	0.07	0.50	0.34	0.30	0.07
Dental laboratory work	0.23	0.32	0.05	0.07	0.26	0.33	0.05	0.06
High school biology teaching[h]	0.45	0.32	0.27	0.07	0.47	0.32	0.27	0.06
College/university biology teaching[i]	0.66	0.32	0.48	0.07	0.68	0.32	0.48	0.06
Funeral services[g]	0.45	0.32	0.28	0.07	0.48	0.32	0.27	0.06
Metalwork machine operation	0.28	0.32	0.10	0.07	0.30	0.33	0.09	0.06
All others[j]	0.24	0.32	0.06	0.06	0.26	0.32	0.06	0.06

[a]HE home represents high exposure home, with formaldehyde levels assumed to be 0.40 ppm.

[b]LE home represents low exposure home, with formaldehyde levels assumed to be 0.05 ppm.

[c]Includes urea, phenol, melamine and acetal formaldehyde resin manufacturing.

[d]Urea formaldehyde foam chemicals manufacturing.

[e]Urea formaldehyde concentrates manufacturing.

[f]Assumes 0.2 hour per day exposure at level given in Table 3-4 and the rest of the time "in workplace" at 0.05 ppm.

[g]Assumes 3.2 hours per day exposure at level given in Table 3-4 and the rest of the time "in workplace" at 0.05 ppm.

[h]Assumes 1.0 hour per day exposure at level given in Table 3-4 and the rest of the time "in workplace" at 0.05 ppm.

[i]Assumes 2.0 hours per day exposure at level given in Table 3-4 and the rest of the time "in workplace" at 0.05 ppm.

[j]Assumes full-time exposure at 0.05 ppm.

TABLE 3-11. INDIVIDUAL ANNUAL CUMULATIVE EXPOSURE TO FORMALDEHYDE, PERSONS NOT IN LABOR FORCE (10^3 ppm-hr/yr)

Age category	HE home[a]	LE home[b]
Infants and young children[c] (< 6 years old)	3.12	0.52
School age children[d] (6 - 15 years old)	2.32	0.53
Adults not in labor force[c] (16 - 64 years old)	3.12	0.52
Elderly not in labor force[c] (65 + years old)	3.12	0.52
College and university biology students, medical students, nursing students, and dental students[e]	3.57	1.80

[a]HE home represents high exposure home, with formaldehyde levels assumed to be 0.40 ppm.

[b]LE home represents low exposure home, with formaldehyde levels assumed to be 0.05 ppm.

[c]Time allocation assumed to be similar to that of housewives (see Figures 3-5 and 3-6).

[d]Daily time allocation for school age children is assumed to be as outlined in text (see Figures 3-7 and 3-8). It is assumed that children attend school 180 days per year.

[e]Daily time allocation assumed similar to that of employed males (see Figures 3-1 and 3-2). Exposure is assumed to be at levels given in Table 3-4 for five hours per day. Remaining portion of time "in workplace" is assumed to be at formaldehyde levels of 0.05 ppm.

TABLE 3-12. INDIVIDUAL ANNUAL CUMULATIVE EXPOSURE TO FORMALDEHYDE, PERSONS IN LABOR FORCE (10^3 ppm-hr/yr)

Industry	Male		Female	
	HE home[a]	LE home[b]	HE home[a]	LE home[b]
Formaldehyde manufacturing	3.18	1.42	3.25	1.27
Formaldehyde resin manufacturing[c]	5.18	3.42	4.97	2.98
Hardwood plywood manufacturing	3.65	1.88	3.65	1.67
Particleboard manufacturing	4.65	2.89	4.51	2.53
Wood furniture manufacturing	4.96	3.20	4.79	2.80
Mobile home manufacturing	3.05	1.29	3.14	1.16
UFF chemicals manufacturing[d]	3.24	1.48	3.31	1.32
UFFI installation	3.30	1.54	3.36	1.38
Metal molds/castings manufacturing	2.90	1.14	3.01	1.03
Plastic products manufacturing	2.75	0.99	2.89	0.90
Paper/paperboard manufacturing	2.25	0.76	2.68	0.70
Textiles manufacturing	3.09	1.33	3.18	1.19
Apparel manufacturing	3.56	1.80	3.58	1.59
Apparel wholesaling	3.01	1.25	3.11	1.12
Building paper/board manufacturing	4.65	2.88	4.51	2.53
Paints/coatings manufacturing	2.45	0.69	2.63	0.64

(continued)

TABLE 3-12 (continued)

Industry	Male HE home[a]	Male LE home[b]	Female HE home[a]	Female LE home[b]
Abrasive products manufacturing	4.54	2.78	4.42	2.44
Asbestos products manufacturing	4.54	2.78	4.42	2.44
UF concentrates manufacturing	3.18	1.42	3.25	1.27
Nitrogenous fertilizer manufacturing	3.99	2.23	3.95	1.96
Other large volume formaldehyde derivatives manufacturing	3.18	1.42	3.25	1.27
Poultry eggs producing and hatching[f]	2.40	0.64	2.57	0.61
Mushroom farm operation[g]	2.52	0.76	2.68	0.72
Medical/pathology laboratory work	4.01	2.25	3.96	1.98
Dental laboratory work	2.26	0.50	2.47	0.48
High school biology teaching[h]	3.57	1.80	3.73	1.77
College/university biology teaching[i]	4.83	3.06	4.99	3.03
Funeral services[g]	3.59	1.83	3.76	1.80
Metalwork machine operation	2.54	0.78	2.70	0.72
All others[j]	2.32	0.52	2.44	0.52

[a]HE home represents high exposure home, with formaldehyde levels assumed to be 0.40 ppm.

[b]LE home represents low exposure home, with formaldehyde levels assumed to be 0.05 ppm.

TABLE 3-12 (continued)

[c] Includes urea, phenol, melamine and acetal formaldehyde resin manufacturing.

[d] Urea formaldehyde foam chemicals manufacturing.

[e] Urea formaldehyde concentrates manufacturing.

[f] Assumes 0.2 hour per day exposure at level given in Table 3-4 and the rest of the time "in workplace" at 0.05 ppm.

[g] Assumes 3.2 hours per day exposure at level given in Table 3-4 and the rest of the time "in workplace" at 0.05 ppm.

[h] Assumes 1.0 hour per day exposure at level given in Table 3-4 and the rest of the time "in workplace" at 0.05 ppm.

[i] Assumes 2.0 hours per day exposure at level given in Table 3-4 and the rest of the time "in workplace" at 0.05 ppm.

[j] Assumes full-time exposure at 0.05 ppm.

the calculation of yearly exposures is based on 50 workweeks per year (five workdays and two days off per week), and 2 weeks of vacation with time allocation corresponding to days off. School age children are assumed to have 180 school days per year and to allocate time as for nonschool days for the remainder of the year. Housewives, infants, and young children, adults not in the labor force, and elderly not in the labor force are assumed to have cumulative yearly exposures equal to 52 regular weeks (six weekdays and one Sunday per week).

Among the persons not participating in the labor force shown on Table 3-11, school age children have the lowest cumulative exposures for both categories of homes and all days except Sunday in LE homes. Exposures for the infants and young children, school age children, adults not in labor force, and elderly not in labor force are about 70 percent lower than for college and university students and other students exposed in laboratory settings and living in LE homes.

Cumulative exposures for those who are occupationally exposed are given in Table 3-12. The results reflect the twenty-four hour TWA exposures presented in Table 3-10. The industries with the highest cumulative exposure for both male and female employees are formaldehyde resin manufacturing, particleboard manufacturing, wood furniture manufacturing, building paper and board manufacturing, abrasive products and asbestos products manufacturing, and college and university biology teaching.

It is interesting to note that the nonparticipants in the labor force who live in HE homes, excepting school age children (Table 3-11), have higher cumulative annual exposures than 40 percent of those individuals who work in HE occupations and live in HE homes. When living in LE homes, these subgroups experience lower cumulative exposure than almost every occupational subgroup participating in the labor force.

As yet, there is no way to evaluate the magnitude of cumulative exposures. There is still no agreement on whether cumulative exposures are of greater significance than are TWA exposures in determining adverse effects from formaldehyde (Hendrick et al., 1982; Hattis et al., 1981). However, cumulative annual exposures provide a context for evaluating the conditions under which an individual will experience relatively greater exposures to formaldehyde. Cumulative exposures are measured in ppm-hr per unit time so that conversion to inhaled concentrations can be made when further epidemiologic research delineates harmful levels.

The estimates presented in this report are subject to the limitations of the available data. Individual activities may alter exposures to a great extent, unaccounted for in this data set. Two examples are smoking and cooking with gas appliances.

Smoking emits formaldehyde at the rate of 0.02 to 0.04 mg per cigarette smoked. A person smoking 15 cigarettes per day inhales 0.25 to 0.50 ppm of formaldehyde. Sidestream smoke from 10 cigarettes may increase ambient levels by 0.20 ppm (Versar, 1982). The Statistical Abstract of the U.S. (1982-83) reported that in 1980 there were 15,200 persons smoking less than 15 cigarettes per day, 21,806 persons smoking 15 to 24 cigarettes per day, 6,800 persons smoking 25-34 cigarettes per day, and 7,945 persons smoking 35 or more cigarettes per day. Of these, 53 percent were males and 47 percent were females. Persons in the 25 to 44 year old age group accounted to 44 percent of all smokers.

Gas stoves emit 15,000 ug per hour from top burners and 25,000 μg per hour from ovens. Assuming both burners and ovens are operated for three hours per day, this usage represents a total emission of 100 ppm of formaldehyde per day. There were 37,936 homes in the U.S. in 1980 using utility gas, bottled gas, tank gas, or liquid propane gas as a cooking fuel (Statistical Abstract of the U.S., 1982-83). Given the energy efficiency of modern homes, this may represent a substantial increase in indoor levels of formaldehyde in homes which might otherwise be considered low exposure homes. Similarly, use of gas as a heating fuel may elevate indoor exposure levels.

The factors described throughout this chapter complicate the grouping of the U.S. population into exposure categories. More data are needed on lifestyles of subgroups at risk from elevated formaldehyde exposures, and on the formaldehyde concentrations present in various locations.

3.5 REFERENCES

Bardana, Emil J., 1980. "Formaldehyde Hypersensitivity and Irritant Reactions at Work and in the Home." Immunology and Allergy Practice II (3):11-23.

Becker, Gary S., 1965. "A Theory of the Allocation of Time." The Economic Journal 75(299):493-517.

Brail, Richard K., and F. Stuart Chapin, Jr., 1973. "Activity Patterns of Urban Residents." Environment and Behavior 5(2):163-190.

Chapin, F. Stuart, Jr., 1974. Human Activity Patterns in the City - Things People Do In Time and In Space. New York: Wiley and Sons.

Chapin, F. Stuart, Jr., and Richard K. Brail, 1969. "Human Activity Systems in the Metropolitan United States." Environment and Behavior 1:107-130.

Cosmetic Ingredient Review (CIR), 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology 3(3):157-184.

Consensus Workshop on Formaldehyde, 1983. Deliberations of the Consensus Workshop on Formaldehyde. Draft Report. Conference held in Little Rock, Arkansas on October 3-6, 1983.

Dally, Kay A., Lawrence P. Hanrahan, Mary Ann Woodbury, and Marty S. Kanarek, 1981. "Formaldehyde Exposure in Nonoccupational Environments." Archives of Environmental Health 36(6):277-284.

Gammage, R. B., 1981. Final Report to the Canadian Department of Consumer and Corporate Affairs: Product Safety Branch. Report No. DOE/NBM-2020919. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Gammage, R. B., B. E. Hingerty, Thomas G. Matthews, Alan R. Hawthorne, Don R. Womack, Rita R. Westley, and Kailish C. Gupta, 1983. Temporal Fluctuations of Formaldehyde Levels Inside Residences. Report No. DE 83009788. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Gupta, K. C., A. G. Ulsamer, and P. W. Preuss, 1982. "Formaldehyde in Indoor Air: Sources and Toxicity." Environment International. 8:349-358.

Hammer, Philip G. Jr., and F. Stuart Chapin, Jr., 1972. Human Time Allocation: A Case Study of Washington, D. C. Technical Monograph. Chapel Hill, North Carolina: Center for Urban and Regional Studies, University of North Carolina.

Hattis, Dale, Clifford Mitchell, Janet McCleary-Jones, and Nancy Gorelick, 1981. Control of Occupational Exposures to Formaldehyde: A Case Study of Methodology for Assessing the Health and Economic Impacts of OSHA Health Standards. Report No. CPA-81-17. Cambridge, Massachusetts: Center for Policy Alternatives, Massachusetts Institute of Technology.

Hawthorne, A. R., R. B. Gammage, C. S. Dudney, D. R. Womack, S. A. Morris, R. R. Westley, and K. C. Gupta, 1983. Preliminary Results of a Forty-Home Indoor-Air-Pollution Monitoring Study. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Hendrick, David J., Roy J. Rando, Donald J. Lane, and M. Joycelyn Morris, 1982. "Formaldehyde Asthma: Challenge Exposure Levels and Fate After Five Years." Journal of Occupational Medicine 24(11):893-897.

National Institute of Occupational Safety and Health (NIOSH), 1981. Formaldehyde: Evidence of Carcinogenicity. Current Intelligence Bulletin No. 34. U.S. Department of Health and Human Services. 15 pp.

National Research Council (NRC), 1981a. Formaldehyde and Other Aldehydes. Washington, D.C.: National Academy Press.

National Research Council (NRC), 1981b. Indoor Air Pollution. Washington, D.C.: National Academy Press.

Oatway, Janet, and Hans A. Klemm, 1981. Formaldehyde Regulatory Control Options Analysis. Draft Final Report. Contract No. 68-01-5960. Prepared for Office of Chemical Control, Environmental Protection Agency. Report No. GCA-TR-812-1-G. Bedford, Massachusetts: GCA Corporaion.

Pickerall, J. A., L. C. Griffis, and C. H. Hobbs, 1982. Release of Formaldehyde from Various Consumer Products. Final Report. Report No. LMF-93, UC-48. Prepared for Consumer Products Safety Commission. Albuquerque, New Mexico: Lovelace Biomedical and Environmental Research Institute.

Repace, James L., 1982. "Indoor Air Pollution." Environment International 8:21-36.

Robinson, John P., 1977a. How Americans Use Time - A Social-Psychological Analysis of Everyday Behavior. New York: Praeger.

Robinson, John P., 1977b. Changes in Americans' Use of Time: 1965-1975 - A Progress Report. Technical Report for Communication Research Center, Cleveland State University. Cleveland, Ohio: John P. Robinson.

Snell Division, 1979. Preliminary Study of the Costs of Increased Regulation of Formaldehyde Exposure in the United States Workplace. Prepared for Formaldehyde Task Force of the Synthetic Organic Chemical Manufacturers Association. Florham Park, New Jersey: Booz, Allen, and Hamilton, Inc.

Spengler, John D., and Steven D. Colome, 1982. "The Ins and Outs of Air Pollution." Technology Review 85(6):32-44.

Spengler, John D., and Ken Sexton, 1983. "Indoor Air Pollution: A Public Health Perspective." Science 221 (4605):9-17.

Statistical Abstract of the U.S., 1982-83. 103rd edition. Bureau of Census, Department of Commerce.

Szalai, Alexander, ed., 1972. The Use of Time. The Hague, Netherlands: Mouton.

Versar, Inc., 1982. Exposure Assessment for Formaldehyde. Final Draft Report. Contract No. 68-01-6271. Prepared for Office of Toxic Substances, Environmental Protection Agency. Springfield, Virginia: Versar, Inc.

Yocom, John E., 1982. "Indoor-Outdoor Air Quality Relationships - A Critical Review." Journal of the Air Pollution Control Association 32(5):500-520.

CHAPTER 4

VALUATION OF REDUCTIONS IN EXPOSURE RISKS

While exposure to formaldehyde on the job or in the home may be accompanied by a number of acute health risks, the values to workers and consumers of reducing these risks is a major task of regulatory impact analysis. However, the value to individuals of reducing exposure is unknown because no market exists in which they can purchase reductions in health risks from formaldehyde and thereby reveal their valuation. Fortunately, two approaches are available for inferring the value of commodities not traded in markets--revealed preference and expressed preference. The former identifies the value of nonmarket commodities by analyzing changes in the value of market commodities. The latter directly asks people to value nonmarket commodities using one of a variety of techniques. This study uses a variant of the revealed preference approach, the property value method, to measure the values of the reductions in health risks associated with formaldehyde exposure by comparing the prices of homes with elevated formaldehyde concentrations to those with lower concentrations. Our focus is only on valuing risks reductions to people exposed outside the workplace. However, the results are extended to infer the benefits of reducing occupation risks from formaldehyde.

The following sections explain the procedures used to value consumer exposure risks and presents the results of this preliminary effort. Specifically, Section 4.1 briefly summarizes the property value technique for valuing environmental quality, Section 4.2 outlines the specific procedures used in this study, and Section 4.3 describes the data collection methodology. Section 4.4 presents the results, and Section 4.5 contains aggregate benefits estimates.

4.1 THE PROPERTY VALUE METHOD

The property value method has been employed by a number of researchers to estimate the value of improvements in environmental quality. The basic idea behind the technique is that the value of environmental quality is reflected in the value of property. In particular, summarizing Freeman (1979), suppose an individual has the utility function

$$U = U(X,Q) , \qquad (4\text{-}1)$$

where X is a vector of private good quantities and Q is a vector of environmental amenities. Because individuals, in effect, choose their consumption rate for environmental quality, Q, by selecting a specific bundle of private goods, X, the value of any level--or a change in a level--of environmental quality can be estimated by determining how the value of a given private good, X_1, is affected by the level of environmental quality. In Figure 4-1, this value per period is represented (approximately) by area abcd per period. The demand curve D_o for the private good X_1 is drawn conditional on a particular level of environmental quality; demand curve D_1 is drawn assuming a comparatively better level of environmental quality.

Empirical application of this theory typically involves a two-step procedure. In the first step, the implicit value of the marginal unit of environmental quality, the hedonic price function, is estimated using standard regression techniques. Specifically, the observed prices for the market good, X_1, are regressed on the observed quantities of the attributes of the good and environmental quality, Q. For example, where X_1 is houses, the price of houses, P_{X_1}, is regressed on the quantities of the characteristics of the house and neighborhood and on the quantities of environmental quality. The house characteristics include house-specific attributes (size, square feet, number of bathrooms, etc.) and site- or neighborhood-specific attributes (distance from schools, fire station, etc.). The marginal implicit price of any characteristic--e.g., environmental quality--is $\partial P_{X_1}/\partial Q_j$, the partial derivative of the regression equation. This price is the estimated value of a small change in environmental quality. As described by Freeman (1979), the estimated implicit price function is the sought-after inverse demand function as long as the changes in environmental

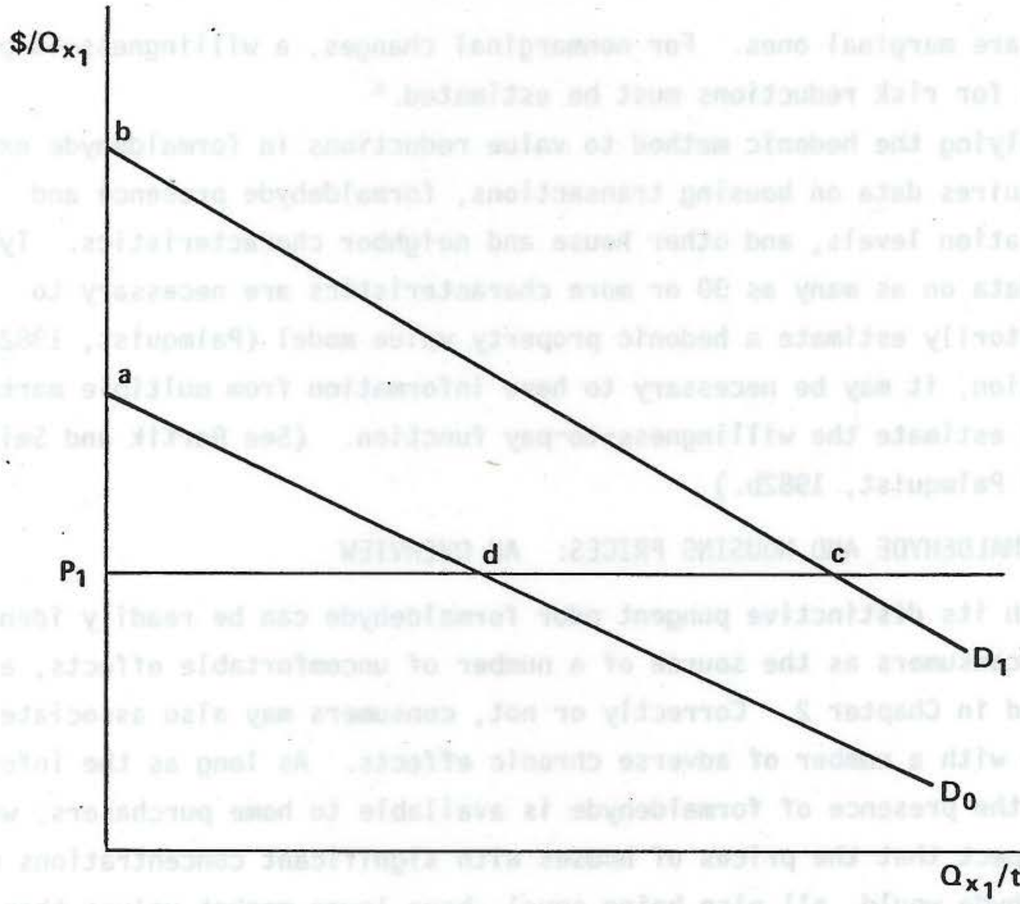


Figure 4-1. Benefits of environmental quality changes.

quality are marginal ones. For nonmarginal changes, a willingness-to-pay function for risk reductions must be estimated.*

Applying the hedonic method to value reductions in formaldehyde exposure requires data on housing transactions, formaldehyde presence and concentration levels, and other house and neighbor characteristics. Typically, data on as many as 30 or more characteristics are necessary to satisfactorily estimate a hedonic property value model (Palmquist, 1982a). In addition, it may be necessary to have information from multiple market areas to estimate the willingness-to-pay function. (See Bartik and Smith, 1984 and Palmquist, 1982b.)

4.2 FORMALDEHYDE AND HOUSING PRICES: AN OVERVIEW

With its distinctive pungent odor formaldehyde can be readily identified by consumers as the source of a number of uncomfortable effects, as described in Chapter 2. Correctly or not, consumers may also associate exposure with a number of adverse chronic effects. As long as the information on the presence of formaldehyde is available to home purchasers, we would expect that the prices of houses with significant concentrations of formaldehyde would, all else being equal, have lower market values than those with lower concentrations. These differences could be estimated with the hedonic approach, but that effort is beyond the scope of this study.

As an alternative, we have used a variant of the hedonic approach similar to the resale technique that Palmquist (1982a) used to determine how individuals value reductions in highway noise levels. In particular, we used price information collected in a small-scale realtor survey to compare the sales price of houses with and without urea-formaldehyde foam insulation (UFFI). Specifically, we asked realtors who were knowledgable about the effect of UFFI on house prices to identify UFFI-containing houses that had recently sold in their market area. For each identified house, we elicited the actual sale price and their best estimate of what that price would have been had the house not contained UFFI. Hence, all other houses

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*By assuming that our changes in risk are marginal ones, we have skirted the complex estimation and conceptual issues discussed in Bartik and Smith [1984]. While this assumption is more acceptable in a preliminary assessment, it would require more careful consideration in a formal hedonic property value study.

and market characteristics (including the time-dependent variables that must be accounted for in the repeat sales technique) remain constant. The critical assumption in this approach is that realtors know and accurately report the price of the houses without UFFI. In effect, we ask the realtors to perform the hedonic estimation based on their knowledge of market values. This is in the same spirit of eliciting experts encoding of probabilities instead of estimates based on actual data.

4.3 SURVEY METHODOLOGY

In accordance with Office of Management and Budget (OMB) regulations for nonapproved surveys, we limited the survey sample to nine individuals.* Thus, we mailed the questionnaire, instructions, and cover letter reproduced in Appendix A to three realtors from each of three geographically diverse northern metropolitan areas. The selected geographic regions reflect areas where UFFI has been installed extensively, primarily single-family houses predominantly in the northern portion of the United States. The chosen metropolitan areas are from three northern regions--the Northeast, the North Central, and the Pacific Northwest.

Officials from state realtor boards and from an independent air quality testing laboratory identified local realtors who had some experience selling homes containing UFFI. From this group, we contacted realtors in Tacoma, Washington; Hartford, Connecticut; and Milwaukee, Wisconsin, to verify their familiarity with UFFI homes and to determine their willingness to participate in the survey. In addition, we selected three realtors from each of these areas to report particular characteristics of recently sold, UFFI-containing homes. These characteristics were similar to items found on the multiple listing form and have been determined to relate to the appraised value and selling price of a home. The realtors reported details about the sale of the UFFI-containing homes, including whether the buyer was aware of the presence of the UFFI and whether this awareness had an

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*OMB regulations require a sometimes lengthy review and approval process for efforts that would collect information from more than nine individuals. The project schedule did not permit us to pursue approval of a larger sample size for this effort.

an effect on the list price or on the sale price of the home. In addition, we obtained estimates of what the house would have sold for without UFFI.

Finally, the nine realtors provided information about their general impressions of the impact of UFFI on the housing market. In particular, we asked them whether list price, sale price, and length of time a home remains on the market are generally affected by the presence of the UFFI. Where relevant, we also sought information on the quantitative effects the UFFI had on each of these three variables. Other sources of information--such as state public health authorities, state realtor's association officials, and personnel in testing laboratories who assess formaldehyde levels in UFFI-containing homes--were evaluated to supplement the local realtors' responses.

4.4 RESULTS

Nine respondents provided information on a total of 13 recent sales of UFFI-containing houses in their market area. Table 4-1 provides data on these houses. As expected, they tend to be older houses; the average age is 66 years. UFFI was installed about 5 years ago in most of these houses; 5 years is also about the half-life of formaldehyde. This suggests that formaldehyde was still present in sufficient concentrations to be noticed.

Table 4-2 provides the actual sale price of each of the houses in the sample and the realtors' estimates of the price if the houses had not contained UFFI. As shown in the table, there is substantial variation in the results. In particular, for over half the sample (seven houses), no reduction in value was reported for the presence of UFFI. For one house, moreover, the realtor indicated that UFFI actually increased the sale price--a counterintuitive result. However, a followup telephone discussion with the respondent indicated that other unusual circumstances in the sale affected the price of the house. We omitted this response in the following analysis.

In addition to listing actual and estimated sale prices, Table 4-2 also summarizes information about the buyer's awareness of the UFFI in the house. In every case, the buyer was aware that UFFI was in the home. Realtors in all three states indicated that it is standard practice to

TABLE 4-1. CHARACTERISTICS OF UFFI-CONTAINING HOUSES

Observation code[a]	Interior floor area (ft²)	Number of baths	Lot size (ft²)	Garage size (cars)	Age of house (years)	Style of house	Locale (U/C/NU)[b]	Year of UFFI installation	Age of UFFI (years)
1	1,200	1.5	7,004	1	64	Colonial	U	1978	3
1	2,000	3.5	17,500	2	54	Eng. Tudor	U	1979	5
1	1,000	1.0	10,000	0	27	Ranch	NU	1979	3
1	1,600	1.5	20,000	0	175	Colonial	NU	pre-1982	-
2	2,400	1.0	4,800	2	50	Duplex	U/C	1977	6
2	1,818	1.0	7,119	2	69	Cape Cod	U/C	1978	5
2	1,400	1.75	21,780	0	30	Cape Cod	NU	Unknown	-
2	1,200	1.0	10,000	0	100	2-story	NU	1977	2
2	2,000	1.75	217,800	4	100	2-story	NU	1978	6
3	3,800	1.5	6,240	3	73	Victorian	U/C	1979	5
3	1,313	1.0	6,000	1	75	1.5-story	U/C	1976	7
3	940	1.0	20,000	1	20	Ranch	NU	Unknown	-
3	3,356	2.5	12,350	3	16	2-story	U	1976	7
Average	1,848	1.5	27,738	1.5	66	--	--	--	4.9
Standard deviation	680	0.5	55,168	1.0	41	--	--	--	1.6

[a] 1 = Connecticut; 2 = Wisconsin; 3 = Washington.

[b] U represents "urban," C represents "within the limits of the central city," and NU represents "nonurban."

TABLE 4-2. ACTUAL AND ESTIMATED SALES PRICES FOR UFFI-CONTAINING HOUSES

Observation code[a]	Date of sale (month/year)	Actual sale price ($)	Realtor's estimated sale price without UFFI ($)	Sale price difference ($)	Sale price difference (%)	Buyer aware of UFFI[b]	Presale testing[b]
1	02/81	64,000	72,500	-8,500	-13.3	1	1
1	09/84	178,000	178,000	0	0.0	1	1
1	10/82	31,000	52,000	-21,000	-67.7	1	1
1	09/83	46,500	65,000	-18,500	-39.8	1	1
2	05/83	59,900	62,500	-2,600	-4.3	1	1
2	10/83	62,900	62,900	0	0.0	1	1
2	01/84	46,900	45,000	1,900[c]	4.0[c]	1	1
2	09/79	46,000	46,000	0	0.0	1	0
2	08/84	58,000	58,000	0	0.0	1	0
3	03/84	64,500	64,500	0	0.0	1	1
3	06/83	47,500	47,500	0	0.0	1	1
3	10/83	52,500	52,500	0	0.0	1	0
3	11/83	142,000	150,000	-8,000	-5.6	1	1

[a]1 = Connecticut; 2 = Wisconsin; 3 = Washington.

[b]0 = No
1 = Yes

[c]The respondent reported unusual circumstances of sale and did not attribute the positive difference to the presence of UFFI.

disclose the presence of the product, even where disclosure is not required by law. Moreover, in 10 of 12 cases, the homes were tested for formaldehyde concentrations before the sale was completed. According to realtors, testing is recommended to assure the buyer of low risks. Testing would be expected to be negatively correlated with the price differential, but little variation occurred in this sample.

Table 4-3 provides means for the entire sample and for each state separately. Before computing the means, we adjusted the sale price data to 1984 values using the implicit GNP price deflator for nonfarm residential structures. This was necessary because the date of sale varied by as much as 3 years in some cases.

As shown in Table 4-3, the average effect of UFFI for the sample is to reduce house prices $5,044 or 6.5 percent (Table 4-3).* The state averages in Table 4-3 show considerable differences across the states. In particular, for Connecticut, the average sale price difference is 13.2 percent, substantially larger than the differences for Wisconsin and Washington. Location may affect price differentials in two ways: climate differences across regions affect formaldehyde emissions (see Chapter 3) and levels of awareness of UFFI and concern for its presence in a home may differ due to publicity generated in an area. Thus, the price differentials for Connecticut may be larger than those for Wisconsin and Washington because the State ban on UFFI heightened public awareness of the health risks of formaldehyde exposure.

The results reported in Tables 4-1 through 4-3 are very tentative, since none of the means is significantly different from zero, even at the 0.10 level. A larger sample drawn from different locations within each state would obviously provide a better basis for calculating and comparing mean differences in price due to the presence of UFFI in a house. However, despite the possible limitations of sample size, the survey results are supported by anecdotal evidence. For example, realtors in Connecticut and Wisconsin reported that mortgage companies were refusing loans for UFFI

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*Alternatively stated, removal of UFFI from these homes and replacement with a similar-performing material, in terms of insulating qualities but without the health effects of UFFI, would raise the market value of these houses an average of 10.9 percent, all other factors being unchanged.

TABLE 4-3. AVERAGE SALE PRICE DIFFERENCES FOR UFFI-CONTAINING HOUSES

Observation code[a]	Number of houses	Average actual sale price (1984$)[b,c]	Average estimated sale price without UFFI (1984$)[b,c]	Average absolute increase in value without UFFI (1984$)[c]	Average sale price difference ($)	Average sale price difference (%)[d]
1	4	81,525 32,296 - 178,000	93,966 54,174 - 178,000	12,441	-12,441	-20.1 (17.9)
2	4	60,075 57,687 - 63,829	60,735 57,687 - 152,216	660	-660	-1.0 (2.1)
3	4	77,518 48,202 - 144,097	79,548 48,202 - 152,216	2,030	-2,030	-1.3 (2.7)
All	12	73,039 32,296 - 178,000	78,083 48,202 - 178,000	5,044	-5,044	-7.5 (13.3)

Note: One observation is excluded because it does not represent the effects of UFFI on the sale prices of houses.

[a] 1 = Connecticut; 2 = Wisconsin; 3 = Washington.

[b] Ranges for sample are reported beneath the averages.

[c] Conversion to 1984 dollars using implicit GNP price deflator for nonfarm residential structures.

[d] Values in parentheses are standard deviations.

homes strictly because they contained the insulation.* Further, the nine realtors were asked for their general impressions of the effect of the presence of UFFI on sale price and time on the market. As reported in Table 4-4, about half the respondents believe that the presence of UFFI reduces the sale price and increases the time required to sell the house.

The length of time a home is on the market should relate to the price a seller receives for the home. An analogy may be drawn to rental markets. Stull (1978) has shown that, at a given price, some proportion of the total number of potential tenants will rent an apartment. After a length of time, if the apartment is not rented, the landlord follows a sequence of price (rent) reductions that is decreasing over time. At each lower price, a larger proportion of the potential renters is available. At the equilibrium price, then, the unit will be rented. Ideally, it would be desirable to model the interaction of list price, time on market, and sales price for UFFI- and non-UFFI-containing houses.

Finally, we can estimate a simple model to identify factors besides the presence of UFFI that may account for the price differentials:

$$R = f(Z,S,L) \ , \qquad (4\text{-}2)$$

where R represents the differential in prices, Z represents characteristics of the house, S represents characteristics of the sale, and L represents characteristics of the location. For this application, we selected a linear form for the regression equation. The model estimated is

$$R = \beta_0 + \beta_1 WI + \beta_2 WA + \beta_3 TIMEMKT + \beta_4 SPRING + \beta_5 SALE + e \ , \qquad (4\text{-}3)$$

where R represents the percentage differential in the price for houses without UFFI and the actual sale price of the homes with UFFI, WI and WA represent location dummy variables for Wisconsin and Washington, respectively, TIMEMKT represents the length of time in months that a UFFI home is on the market, SPRING is a dummy variable for the months February through July, SALE represents the actual sale price of the UFFI home, and e is a normally distributed error term.

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*A survey of appraisers conducted in 1983 by Runzheimer (1983) indicated that 19 percent of 98 respondents adjusted home values when UFFI was present. Average adjustments were 14 percent of the value of the home, with a range from 5 percent to 40 percent.

TABLE 4-4. RESPONDENT PERCEPTIONS OF THE EFFECT OF UFFI ON SALE PRICES AND TIME ON MARKET

Respondent	Percentage change in sale price due to UFFI	Excess time on market due to UFFI (months)
1	-10	3 - 4
2	-15	>6
3	-10	3 - 4
4	0	>6
5	0	0
6	0	0
7	0	0
8	-10	3 - 4
9	-20-30	0[a]

[a]Respondent replied ">6 if not priced to allow for UFFI."

The parameter values for the estimated model are given in Table 4-5. The intercept and the variables WI and WA are significant at least at the 0.05 level. The intercept, representing CT, displays a positive sign. This may reflect the substantial adverse publicity due to the statewide ban on the sale of UFFI. The coefficients associated with WI and WA are negative. This may reflect indifference to the presence of UFFI or less awareness of the potential health effects on the part of the buyers in these states. Climate factors influencing offgassing and subsequent health problems due to the UFFI could also be involved.

TIMEMKT and SPRING are not significant for this data set, even at the 0.10 level. These results contradict intuitive suppositions. Possibly, the very small size of the data set and its restriction to only three metropolitan areas failed to generate enough variation in the sample to capture these effects. The coefficient associated with SALE is significant at the 0.05 level but had a very small magnitude. The negative sign implies that clean indoor air is probably a normal good. Overall, the R^2 value of 0.75 indicates that the model explains about 75 percent of the sample variation in the price differential. These results should be considered very preliminary because of the small sample size. Nevertheless, the results seem plausible and suggest that more detailed investigations would offer promise.*

4.5 ESTIMATES OF AGGREGATE BENEFITS

The data on exposures and house price differentials are used here to develop some very preliminary approximations of the aggregate benefits of reductions in formaldehyde exposures. The results are only suggestive and may not even represent order of magnitude values. However, they do suggest the value of the information obtained in a benefits assessment.

The survey--which had a small number of observations, nonrepresentative, and based on opinion--indicated that the average price differential between UFFI and non-UFFI homes was $5,044. This value is assumed here to

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*Other variables considered for analysis included whether homes had been tested for formaldehyde levels, the age of the UFFI, and the interior area of the home. Regressions including these variables generated nonsignificant coefficients.

TABLE 4-5. RESULTS OF REGRESSION ANALYSIS

Variable	Parameter estimate	T for Ho: parameter = 0
INTERCEPT	0.335341	4.270[a]
WI	-0.236886	-3.428[b]
WA	-0.177108	-2.719[b]
TIMEMKT	0.002844	0.392
SPRING	-0.065274	-1.112
SALE	-0.000002	-2.437[b]
R-SQUARE	0.7513	
F VALUE	3.624[c]	

[a]Significant at $\alpha = 0.01$.
[b]Significant at $\alpha = 0.05$.
[c]Significant at $\alpha = 0.10$.

represent the equilibrium, capitalized marginal willingness to accept value that individuals require to incur formaldehyde exposures in concentrations found in the home. To convert this value into a marginal annual willingness-to-accept value requires adjusting for income and property taxes and consumer rate of time preference. Following Freeman (1979), this annual value, r, can be calculated from the capitalized value, k, using estimates of the rate of time preference, i, the ad valorum tax rate, t, and the marginal income tax rate, g. Using assumed values for these parameters,

$$\begin{aligned} r &= k(i+t)(1-g) \\ &= 5044(0.10 + 0.01)(1-0.25) \\ &= 416. \end{aligned}$$

Further, assuming the average number of family members per household is 2.3, the per capita annual value would be $181.

We estimate about 5,250 million prople are currently exposed to high levels of formaldehyde in the home. An approximate measure of the dollar value of the benefits to these individuals of the complete elimination of all elevated formaldehyde concentrations would, therefore, be $950 million annually.

People are also exposed to high concentrations of formaldehyde on the job. These individuals would also benefit if the formaldehyde to which they are exposed daily were eliminated. Assume comparability between the concentrations they experience in the workplace and those found in UFFI houses, and assume that they would similarly value reduction in exposure. First, adjust the household value for the difference in the length of exposure on the job (8 hours per day, 5 days per week, 50 weeks per year) and that in the home (14 hours per day, 7 days per week, 50 weeks per year):

$$(181)(.41) = \$74.$$

We estimate about 1,863 million workers are currently exposed to formaldehyde. Their approximate valuation of the benefits of completely eliminating all formaldehyde exposures on the job would, therefore, be about $138 million annually. Summing the value to consumers and workers yields an aggregate annual benefit of $1.1 billion annually.

Finally, we again caution about the preliminary nature of our estimates. Our estimates are based on very limited information and very restrictive simplifying assumptions. Under these conditions, any confidence interval about the mean must be very broad.

4.6 IMPLICATION

In this chapter, we have provided preliminary estimates of the benefits of reducing formaldehyde exposures under TSCA. In so doing, we have tried to provide an organizational structure consistent with economic principles. Although the project scope and schedule permitted us to use only the crudest methods and data, the magnitude of the potential benefits of reducing formaldehyde exposures is potentially large--sufficiently large, in fact, to suggest that investing in better benefits information may prove quite useful to EPA decisionmakers.

Sensible benefits analysis requires a matching of method and the magnitude of the problem; we suggest that the returns to additional analysis would prove positive. In particular, the foregoing analysis suggests that the nature of the formaldehyde problem is well-matched to either the hedonic or the contingent valuation approaches for benefits assessment. The commodity is relatively well defined, its effects are reasonably well documented, and consumers in housing markets are pretty consistently aware of its presence (or absence). These characteristics make additional benefits research considerably more attractive. In fact, formaldehyde would appear to present an excellent case study for a comparison of the two benefits approaches.

4.7 REFERENCES

Bartik, Timothy J., and V. Kerry Smith, 1984, "Urban Amenities and Public Policy," forthcoming in Handbook of Urban Economics, E. S. Mills, ed., review draft, May 1984.

Cohen, David, 1983. "Legal Dimensions of the UFFI Problem." Canadian Business Law Journal 8:309-373.

Freeman, A. Myrick, III, 1979. The Benefits of Environmental Improvement--Theory and Practice. Baltimore: Resources for the Future.

Palmquist, Raymond B., 1982a. "Measuring Environmental Effects on Property Values Without Hedonic Regressions." Journal of Urban Economics, 11:333-347.

Palmquist, Raymond B., 1982b, "The Demand for Housing Characteristics: Reconciling Theory and Estimation," unpublished paper, Department of Economics, North Carolina State University, Raleigh, North Carolina, July 1982.

Runzheimer Reports on Relocation, 1983. "Homes Discounted for 'Aggravation Factor.'" Trade newsletter. 2(6):5.

Stull, William J., 1978. "The Landlord's Dilemma--Asking Rent in a Heterogeneous Housing Market." Journal of Urban Economics 5:101-115.

CHAPTER 5

PUBLIC AND PRIVATE SECTOR RESPONSES TO THE FORMALDEHYDE PROBLEM

As information has become available on the health effects of exposure to formaldehyde governments, firms, trade organizations, citizen groups, and individuals have responded in a number of ways. In the public sector various policy initiatives have been considered and some adopted that reduce the likelihood of exposure, inform people of the risks of exposure, or compensate damaged parties. In the private sector various organizations and groups have sought to educate the public on the risks of exposure and have lobbied for government intervention. Damaged parties have sued for damages. Firms have disclosed formaldehyde levels in products to potential consumers. Producers and consumers have tested for the presence of formaldehyde and taken action to remove formaldehyde-containing materials already in place. Producers have substituted away from formaldehyde in production, and consumers have sought products without formaldehyde. This chapter documents some of these public and private sector responses.

5.1 PUBLIC SECTOR RESPONSES

Several types of policy options are available and have been utilized by governments to reduce people's exposure to formaldehyde. These options include:

- Exposure standards
- Evaluation programs
- Product and use standards
- Product bans
- Information disclosure requirements
- Compensation schemes.

This section summarizes the responses to the formaldehyde problem by all levels of government in the United States for which information is available from secondary sources. The responses of foreign governments are also summarized.

5.1.1 Exposure Standards

Exposure standards are a key feature of most governments' attempts to promote public health. They set upper limits on exposures to pollutants for targeted populations. Compliance may be achieved by a number of means including the use of engineering controls, changes in production methods or product design, or by use of personal protective equipment such as respirators by potentially exposed individuals. In some cases voluntary compliance may be assumed. However, some enforcement mechanism is generally a prominent component of an exposure standards policy.

Exposure standards are usually based on known or suspected threshold levels of harm. In the case of formaldehyde, these thresholds are not known precisely, but, as summarized in Chapter 2, some ranges of exposure which result in adverse health consequences have been identified.

Compliance with formaldehyde exposure standards is complicated because the formaldehyde offgassing from products, or release of fumes, varies with environmental conditions. In particular, high humidity and high temperature are conducive to offgassing. In any area that is not environmentally controlled, the rates of offgassing and the subsequent exposure to formaldehyde fumes will vary with the climatic conditions. This result has been shown by Pickerell et al. (1982), Gammage (1981), and Gammage et al. (1983), and Hawthorne et al. (1983). Also, the offgassing decreases over time, so that older materials tend to produce less fumes than newer materials (Hawthorne et al., 1983; Dally et al., 1981).

The two types of formaldehyde exposure standards in use--occupational and nonoccupational--are summarized below.

5.1.1.1 Occupational Standards--

Standards that limit exposures to formaldehyde on the job are in place in the United States and most industrialized nations. In the United States (see Table 5-1) OSHA has promulgated a standard limiting the eight-hour

TABLE 5-1. UNITED STATES OCCUPATIONAL STANDARDS FOR FORMALDEHYDE

Agency or State	Standard (ppm)	Type of standard
Occupational Safety and Health Administration (OSHA)	3.0[a]	TWA[c]
	5.0[a]	8-hour ceiling
Florida	5.0[a]	8-hour ceiling
Hawaii	10.0[a]	8-hour ceiling
Massachusetts	3.0[a]	8-hour ceiling
Mississippi	5.0[a]	8-hour ceiling
Pennsylvania	5.0[a]	TWA[c]
	5.0[a]	5-minute ceiling
South Carolina	5.0[a]	8-hour ceiling
American Conference of Governmental Industrial Hygienists (ACGIH)	2.0[b]	8-hour ceiling
National Institute of Occupational Safety and Health (NIOSH)	1.0[b]	8-hour ceiling

[a]Promulgated.

[b]Recommended.

[c]Time-weighted average.

SOURCE: National Institute of Occupational Safety and Health (NIOSH), 1976. <u>Criteria for a Recommended Standard ... Occupational Exposure to Formaldehyde</u>. Department of Health, Education, and Welfare. DHEW (NIOSH) Publication No. 77-126. pp. 161-162.

time-weighted average workplace exposure to 3.0 parts per million (ppm) and the exposure ceiling at 5.0 ppm. Some states have also promulgated occupational standards for formaldehyde. The six states that are known to have standards and their standards are shown in Table 5-1. Other states may also have standards but if so, the information is not readily available. Of the six states only Massachusetts has a more stringent standard than OSHA.

The American Conference of Governmental Industrial Hygienists (ACGIH) and the National Institute of Occupational Safety and Health (NIOSH) have both recommended standards more stringent than OSHA's. The ACGIH recommended standard of 2.0 ppm eight-hour ceiling has been adopted by several foreign governments in setting recommended or actual standards for the workplace exposures to formaldehyde (Geomet, Inc., and Techology and Economics, Inc., 1980). NIOSH recommends a 1.0 ppm eight-hour ceiling.

Although there appears to be a tendency for foreign countries to adopt U.S. occupational standards in the case of formaldehyde, seventeen countries have recommended or promulgated standards stricter than the 3.0 ppm U.S. standard (see Table 5-2). The Soviet Union has the lowest occupational standard at 0.4 ppm, while the United Arab Republic has the highest at 20.0 ppm. The highest value among the industrial countries occurs in Great Britain at 10.0 ppm. No data are available on the degree of compliance with these standards.

5.1.1.2 Nonoccupational Standards--

In the United States there are no national ambient nor indoor air standards. An ambient air standard of 0.1 ppm is recommended by the American Industrial Hygiene Association. In general, ambient air formaldehyde levels tend to be below thresholds for irritation. Urban ambient formaldehyde levels are reported by Versar (1982) to average 0.005 ppm, while rural ambient concentrations average 0.0004 ppm. The National Research Council (NRC) (1981) concluded that ambient formaldehyde levels rarely get higher than 1.0 ppm and are usually less than 0.05 ppm.

The Department of Housing and Urban Development (HUD) recommended a ceiling of 0.4 ppm of formaldehyde in manufactured housing. This action reflects numerous complaints about acute effects suffered by residents of

TABLE 5-2. FOREIGN OCCUPATIONAL STANDARDS FOR FORMALDEHYDE

Country	Standard (ppm)	Type of standard	Reference
Australia	2.0[a]	Ceiling	1
Belgium	2.0[a]	Ceiling	1
Bulgaria	1.0[b]	MPC[d]	1
Czechoslovakia	2.0 [b,c]	TWA[e]	1,2
	4.0 [b,c]	MAC[f]	1,2
Denmark	1.0[b]	TLV[g]	1
Finland	2.0[b]	Ceiling	1
Federal Republic of Germany	5.0[b]	Ceiling	2
	1.0[a]	Ceiling	1
German Democratic Republic	2.0 [b,c]	MAK-D[h]	1
	2.0 [b,c]	MAK-K[i]	1
Great Britain	10.0[b]	Ceiling	2
Hungary	1.0 [b,c]	Ceiling	2
	1.0 [b,c]	TWA[e]	1
Italy	4.0 [b,c]	Ceiling	2
	1.0 [a,c]	TWA[e]	1
Japan	5.0[b]	Ceiling	2
	2.0[a]	TWA,[e] TLV[g]	1
Netherlands	2.0[a]	TLV[g]	1
Poland	4.0 [b,c]	Ceiling	2
	2.0 [a,c]	Ceiling	1
Romania	2.0 [b,c]	Ceiling	2
Sweden	2.0[a]	Ceiling	1
Switzerland	1.0[b]	MAC[f]	1
United Arab Republic	20.0[b]	Ceiling	2
USSR	0.4[b]	MAC[f]	1,2
Yugoslavia	5.0 [b,c]	Ceiling	2

[a]Recommended.

[b]Promulgated.

[c]Standard converted from mg/m³ to ppm, using 1.2 mg/m³ = 1.0 ppm.

[d]Maximum permissible concentration.

[e]Time weighted average.

[f]Maximum allowable concentration.

[g]Threshold limit value.

[h]Maximum average concentration, 8 hour, 45 minute work period.

[i]Maximum concentration not to exceed 30 minutes.

SOURCES:
1. Geomet, Inc., and Technology and Economics, Inc., 1980. An Evaluation of Formaldehyde Problems in Residential Mobile Homes. Final Task 1 Report. Contract No. H-5105. Prepared for Office of Policy Development and Research, Department of Housing and Urban Development. pp. 55-67.
2. National Institute of Occupational Safety and Health (NIOSH), 1976. Criteris for a Recommended Standard ... Occupational Exposure to Formaldehyde. Department of Health, Education, and Welfare. DHEW (NIOSH) Publication No. 77-126. pp. 161-162.

manufactured homes containing substantial amounts of plywood and particleboard (Environmental Protection Agency [EPA], 1984).

Standards for residences have been promulgated in Minnesota for new homes, in Wisconsin for mobile homes, and in California for all residences (see Table 5-3). Both standards have faced court challenges. The Minnesota standard was overturned in the State Supreme Court.

Table 5-4 lists nonoccupational standards recommended or promulgated in foreign countries. Both ambient, or outdoor, and indoor standards are listed. Most of these countries have set or recommended indoor standards at 0.1 ppm. These standards are generally lower than those established or proposed for workplaces (see Table 5-2), perhaps because people often spend more time in homes, and because a wider population is affected.

5.1.2 Evaluation Programs

A survey conducted by the Center for Environmental Health and NIOSH in 50 states and the District of Columbia in 1982 revealed that 29 states have a program or person responsible for evaluating nonoccupational exposures to formaldehyde (Bernstein et al., 1984).

All of these states offer air-sampling services, either free of charge or for a nominal fee, to evaluate such exposures. Table 5-5 (reproduced from Bernstein et al., 1984) describes state practices. In most cases, air sampling is offered based on individual complaints, without supporting diagnosis by a physician. Some states require specific requests for testing by a doctor or the State Health Department.

Comparison air-sampling in unaffected areas of a building or in ambient environments for background purposes is rarely done. Environmental conditions, which affect offgassing rates, are not documentated in over half the programs.

Recommendations are made based on the testing as part of the evaluation process (see Table 5-6, reproduced from Bernstein et al., 1984). Ten states have no criterion or specific exposure level upon which recommendations are based. The advice provided primarily concerns further testing to assess exposure and seeing a physician if symptoms occur. In one state, legal action to reduce exposure is recommended. In seven states, increased ventilation is suggested. In five states, vacating the premises is advised

TABLE 5-3. UNITED STATES NONOCCUPATIONAL STANDARDS FOR FORMALDEHYDE

State or agency	Standard (ppm)	Type of standard	Reference
American Industrial Hygiene Association	0.1[a]	Ambient air	1
U.S. Department of Housing and Urban Development (HUD)	0.4[a]	Ceiling for manufactured housing	2
American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)	0.1[a]	Ceiling for indoor air	3
California	0.2[a]	Ceiling for residences	4
Minnesota	0.8[b,c]	Ceiling for new homes	5
Wisconsin	0.4[b]	Ceiling for mobile homes	1,3

[a]Recommended.

[b]Promulgated.

[c]Overturned in Minnesota State Supreme Court.

SOURCES:
1. Geomet, Inc., and Technology and Economics, Inc., 1980. An Evaluation of Formaldehyde Problems in Residential Mobile Homes. Final Task 1 Report. Contract No. H-5105. Prepared for Office of Policy Development and Research, Department of Housing and Urban Development. pp. 55-67.
2. Environmental Protection Agency (EPA), 1984 "Formaldehyde: Determination of Significant Risk; Advance Notice of Proposed Rulemaking and Notice." Federal Register. v. 49. No. 101. p. 21891.
3. Repace, James L., 1982. "Indoor Air Pollution." Environment International. v. 8. p. 28.
4. Yocom, J. E., 1982. "Indoor-Outdoor Air Quality Relationships - A Critical Review." Journal of the Air Pollution Control Association. v. 32. No. 5. p. 516.
5. Consumer Products Safety Commission (CPSC), 1982. "Ban of UFFI, Withdrawal of Proposed Information Labeling Rule, and Denial of Petition to Issue a Standard." Federal Register. v. 47. No. 64. p. 14368.

TABLE 5-4. FOREIGN NONOCCUPATIONAL STANDARDS FOR FORMALDEHYDE

Country	Standard (ppm)	Type of standard	Reference
Australia	0.1[b]	Ceiling for homes	1
Denmark	0.12[a]	Ceiling for room air	2,3
Federal Republic of Germany	0.1[a]	Ceiling for buildings	1,2
	0.02[b]	Ambient air	1,2
Netherlands	0.1[b]	Ceiling for homes	2,3
Sweden	0.1[a]	Ceiling for new homes	2,3
	0.7[a]	Ceiling for older homes	2,3
USSR	0.01[b]	Ambient air	1

[a]Recommended.

[b]Promulgated.

SOURCES: 1. National Research Council, 1981. Indoor Air Pollution. Washington, D. C.: National Academy Press, p. 511.

2. Geomet, Inc., and Technology and Economics, Inc., 1980. An Evaluation of Formaldehyde Problems in Residential Mobile Homes. Final Task 1 Report. Contract No. H-5105. Prepared for Office of Policy Development and Research, Department of Housing and Urban Development. pp. 55-67.

3. The UFFI Centre, 1983. The UFFI (Urea-Formaldehyde Foam Insulation) File. Information packet published by Consumer and Corporate Affairs Canada. pp. 17-38.

TABLE 5-5. STATE PRACTICES FOR SAMPLING AND ANALYZING NONOCCUPATIONAL EXPOSURES TO FORMALDEHYDE GAS IN 29 STATES

	Number of states
Criteria for Offering Air-Sampling	
Upon receipt of a (biologically plausible) complaint without an MD's diagnosis, and without documentation of exposure	16
Upon request, regardless of symptoms, if a potential source of formaldehyde is present	2
Physician or local health department makes the request	9
Part of state NIAP[a] research project	2
Sampling Strategy and Collecting Device	
Active collection, area samples only, NIOSH Method #125	20
Active collection, area and personal samples, NIOSH #125 plus #318 or #354	1
Active collection, area samples, with use of detector tubes	5
Passive collection, area samples, with use of dosimeter badge	2
Other method (direct-reading instrument)	1
Documentation of Environmental Conditions	
None specified	15
At least temperature and humidity	3
Temperature, humidity, and source data	6
Temperature, humidity, source data, and ventilation characteristics	4
Temperature, humidity, source data, ventilation characteristics, and occupancy/use characteristics	1

[a]National Indoor Air Pollutant.

SOURCE: Bernstein, Robert S., Henry Falk, Douglas R. Turner, and James M. Melius, 1984. "Nonoccupational Exposures to Indoor Air Pollutants: A Survey of State Programs and Practices." American Journal of Public Health. v. 74. No. 9. p. 1021.

TABLE 5-6. STATE PRACTICES FOR EVALUATING AIR-SAMPLING RESULTS AND ADVISING REQUESTORS EXPOSED TO FORMALDEHYDE GAS

Advice for asymptomatic exposed	Number of states (% of 51)
(a) No advice given (or none specified)	5 (10)
(b) Don't worry, don't measure exposures, increase ventilation if concerned	7 (14)
(c) See MD if (biologically plausible) symptoms occur	3 (6)
(d) Exposure monitoring and subsequent advice on abatement are available	5 (10)
(e) Responses (c) plus (d)	9 (18)
(f) Use a passive dosimeter or consult with a commercial laboratory, private contractor, or OSHA[a]	13 (25)
(g) Responses (c) plus (f)	7 (14)
(h) Provide state-prepared fact sheet on formaldehyde hazards	2 (4)
Advice for Symptomatic Exposed	
(a) No advice given (or none specified)	6 (12)
(b) See MD if (biologically plausible) symptoms occur	3 (6)
(c) Exposure monitoring and subsequent advice on abatement are available	4 (8)
(d) Responses (b) plus (c)	15 (29)
(e) Take legal action to reduce exposure	1 (2)
(f) Use a passive dosimeter or consult with a commercial laboratory, private contractor, or OSHA[a]	1 (2)
(g) Responses (b) plus (f)	16 (31)
(h) Vacate premises if (b) and (c) or (f) are not helpful	5 (10)

Evaluation Criteria (Exposure Level) for Adverse Effects	Number of States (% of 29)
None specified	10 (34)
OSHA[a] (3 ppm), acute effects only	1 (3)
CPSC[b] (0.03 ppm), acute effects only	2 (7)
NAS[c] (no threshold), acute effects only	1 (3)
IARC[d] and Federal Panel[e] (lowest feasible level), acute and chronic effects	8 (28)
State or unspecified sources of criteria (0.05-0.5 ppm), acute effects only)	7 (24)

See footnotes on following page.

TABLE 5-6 (continued)

FOOTNOTES

[a]OSHA: Occupational Safety and Health Administration

[b]CPSC: Consumer Product Safety Commission

[c]NAS: National Academy of Sciences

[d]IARC: International Agency for Research on Cancer

[e]Federal Panel on Formaldehyde: a panel of experts designated by OSHA, NIOSH, CPSC, the Environmental Protection Agency, the National Cancer Institute, the Food and Drug Administration, the National Institute of Environmental Health Sciences, and the Department of Energy.

SOURCE: Bernstein, Robert S., Henry Falk, Douglas R. Turner, and James M. Melius, 1984. "Nonoccupational Exposures to Indoor Air Pollutants: A Survey of State Programs and Practices." American Journal of Public Health. 74(9):1022.

as a last resort. No specific advice is given for exposed individuals who do not experience symptons in five states, or for exposed persons who do experience symptoms in six states.

Bernstein et al. (1984) noted that State Health Departments could enhance the level and quality of information on health effects of many indoor air pollutants through coordination. The Federal Interagency Committee on Indoor Air Quality, composed of representatives of EPA, CPSC, DOE, and the Department of Health and Human Services, is suggested by Bernstein et al. (1984) as a possible umbrella agency for this purpose.

5.1.3 Product and Use Standards

Rather than establishing an exposure standard and allowing producers to decide how to best meet the standard, governments can and have regulated products and work practices.

Four distinct areas of product and use standards are listed in Table 5-7: installation and use requirements for urea-formaldehyde foam insulation (UFFI), performance standards, formulation standards, and modified product use standards. These standards are based on the premise that when UFFI is correctly installed, or when products containing formaldehyde are of the correct formulation few problems will result from offgassing.

5.1.3.1 Installation and Use Requirements for UFFI--

The U.S. Department of Energy (DOE), the U.S. Department of Housing and Urban Development (HUD), and the National Bureau of Standards (NBS) all have recommended standards for installation of UFFI. All suggest that UFFI not be installed in attics or ceilings due to enhanced deterioration from the humidity and temperatures usual in these locations (Consumer Product Safety Commission [CPSC], 1980).

France and Sweden have strict standards governing the use of UFFI and its installation. The lack of significant problems in those structures using the insulation is attributed to these standards (UFFI Centre, 1983). California also has rigorous requirements on the use of field-applied UFFI (Repace, 1982). In the United Kingdom, UFFI is recommended for use only in masonry buildings and only under established standards (UFFI Centre, 1983).

TABLE 5-7. PRODUCT AND USE STANDARDS

Regulatory action	Government or agency adopting	Reference
Standards for UFFI installation and/or use	U.S. Department of Energy (DOE)[a]	1
	U.S. Department of Housing and Urban Development (HUD)[b]	1
	National Bureau of Standards (NBS)	1
	California	2
	France	2
	Sweden	2
	United Kingdom	3
Performance standards for formaldehyde emissions	HUD[c]	4
from UFFI	Minnesota	2
	California	2
from wood products	HUD[c]	4
Limitations on content of formaldehyde in foods and food packaging	U.S. Food and Drug Administration (FDA)[d]	5
in cosmetics	FDA[e]	6
	European Economic Community (EEC)[f]	6
Requirements for use of modified product with lower offgassing for UFFI	Spain	1
	Switzerland	1
Limited use of UFFI (de facto)	Austria	1
	Finland	1
	Italy	1
	Japan	1
	Norway	1

See footnotes on following page.

TABLE 5-7 (continued)

FOOTNOTES

[a]Material and foam installation standards for UFFI proposed under Residential Conservation Program.

[b]Use of Materials Bulletin No. 74 describes the conditions for acceptance of UFFI and stipulates limitations on its use.

[c]Proposed requirements stipulate maximums of 0.03 ppm for particleboard and 0.02 ppm for plywood used in manufactured housing.

[d]Formaldehyde approved as a preservative in defoaming agents for processing beet sugar and yeast and in dimethylpolysiloxane defoaming agents. Also approved as a component of resin-bound filters in food contact use, as a component in paper and paperboard in contact with dry food, and as a starch adhesive component. Formaldehyde approved for use in treatment of casein in feed for ruminants. Paraformaldehyde pellets approved for maple sap collection provided formaldehyde content of finished syrup does not exceed 2.0 ppm.

[e]Use of formaldehyde and paraformaldehyde regulated by preset ranges of acceptable concentrations outlined in Title 21, Part 720.4 of the Code of Federal Regulations. Cosmetic Ingredient Review Expert Panel unable to assure safe use of formaldehyde in cosmetics at levels above 0.2 percent.

[f]Maximum concentration for formaldehyde and paraformaldehyde is 0.2 percent for all cosmetics except nail hardeners, oral hygiene products, and aerosol dispensers. Nail hardeners may contain 5 percent formaldehyde and oral hygiene products may contain 0.1 percent formaldehyde. Formaldehyde use in aerosol products, except foams, is prohibited.

SOURCES:

1. The UFFI Centre, 1983. The UFFI (Urea-Formaldehyde Foam Insulation) File. Information packet published by Consumer and Corporate Affairs Canada. pp. 17-38.

2. Consumer Products Safety Commission (CPSC), 1980. "Urea-Formaldehyde Foam Insulation; Proposed Notice to Purchasers." Federal Register. v. 45. No. 113. pp. 39435, 39441.

3. Repace, James L., 1982. "Indoor Air Pollution." Environment International. v. 8. pp. 27-28.

4. Environmental Protection Agency (EPA), 1984. "Formaldehyde; Determination of Significant Risk; Advance Notice of Proposed Rulemaking and Notice." Federal Register. v. 49. No. 101. p. 21891.

5. Versar, Inc., 1982. Exposure Assessment for Formaldehyde. Final Draft Report. Contract No. 68-01-6271. Prepared for Office of Toxic Substances, Environmental Protection Agency. Springfield, Virginia. p. 63.

6. Cosmetic Ingredient Review (CIR), 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology. v. 3. No. 3. pp. 161-162, 179.

At one point in 1977, the Canadian General Standards Board proposed conditions under which UFFI could be acceptably installed, but these were left to the industry to enforce. Subsequent passage of the UFFI ban superseded these voluntary regulations (UFFI Centre, 1983).

5.1.3.2 Performance Standards--

Performance standards set limits on the actual emissions of formaldehyde from the product. Emissions rates, or offgassing, may be substantial, but depending on climate, ventilation, and other factors, the measurable rates in the air may not equal the concentrations found in the fumes (Pickerell et al., 1982; Bowen et al., 1981).

HUD has proposed limits on emissions from plywood and particleboard used in manufactured housing to reduce indoor concentrations in these structures (EPA, 1984). Minnesota and California have actually set performance standards limiting formaldehyde emission from UFFI (CPSC, 1980).

5.1.3.3 Formulation Standards--

Limitations have been set on the amount of formaldehyde or paraformaldehyde permitted in certain products in the United States and in Europe. Formaldehyde use is permitted by the U.S. Food and Drug Administration (FDA) in the processing of certain foods, in packaging materials for foods, and as an additive to animal feeds (Versar, 1982). The FDA allows the use of formaldehyde in cosmetics, in which it serves mainly as an antimicrobial agent (Cosmetic Ingredient Review [CIR], 1984). It restricts formaldehyde concentrations to 5.0 percent in nail hardeners and to lower levels in other products.

A European Economic Community (EEC) Directive imposes maximum concentrations of 0.2 percent free formaldehyde in most cosmetics, 5.0 percent in nail hardeners, and 0.1 percent in oral hygiene products (Cosmetic Ingredient Review [CIR], 1984). Use of formaldehyde in most aerosol products is prohibited.

5.1.3.4 Use of Modified Product--

Improvements in the formulation of UFFI have enabled researchers to reduce offgassing from the product. Modified products are used in Spain and Switzerland, where few significant problems from exposure have been noted. However, the UFFI Centre (1983) states that these products, while better, are "still apparently not the final answer as far as formaldehyde emissions are concerned."

5.1.3.5 Limited Usage--

In several countries, UFFI is in limited use, if at all. For the most part, the stated reasons are that UFFI does not have sufficient insulating properties, or that it is not necessary due to climatic factors. These countries include Austria, Finland, Italy, Japan, and Norway.

5.1.4 Product Bans

Although formaldehyde is a constituent of many products, urea-formaldehyde foam insulation (UFFI) has come under particular scrutiny. UFFI was widely used in residential structures in the middle 1970s to early 1980s as energy prices rose.

In 1982 the CPSC banned the sale of UFFI. This action was based on the results of a study performed by the Chemical Industry Institute of Toxicology (CIIT) which linked nasal cancer to formaldehyde exposure in rats (UFFI Centre, 1983) and on its own finding of acute irritant effects in homeowners exposed to formaldehyde. The CPSC asserted that no feasible safety standard could be devised to protect consumers from the adverse health effects associated with UFFI, so that a ban was the only recourse (Consumer Product Safety Commission [CSPC], 1982). The ban was overturned by the Fifth Circuit Court of Appeals in April 1983 on the grounds that the CPSC failed to demonstrate enough harm from formaldehyde exposure to justify the cost to industry of the ban (see Gulf South Insulation et al. v. United States Consumer Product Safety Commission, 701 F.2d 1137 [1983]).

Bans have been promulgated or considered in several state and local jurisdictions (see Table 5-8). Only two states, Connecticut and Massachusetts, had established bans prior to the CPSC prohibition (CPSC, 1982). Other states considering bans were unable to enact the necessary legislature in the wake of the collapse of the Federal regulation.

Currently, three states have bans on the sale of UFFI, while Colorado has a ban on its use in state-licensed buildings. Several local governments also have enacted regulations to prevent the sale of UFFI in their jurisdictions.

TABLE 5-8. PRODUCT BANS

Regulatory action	Government or agency adopting	Reference
Ban on the sale of UFFI	U.S. Consumer Product Safety Commission (CPSC)[a]	
	Colorado[b]	1
	Connecticut	1
	Massachusetts	1
	New Hampshire	2
	Arvado County, Colorado	1
	Denver County, Colorado	3
	Woodstock, Illinois	2
	Dearborn, Michigan	1
	New York City Building Department[c]	1
	Cincinnati, Ohio	2
	Euclid, Ohio	1
	Seattle, Washington[d]	1
	Canada	4
	Israel	4
Considered ban on sale of UFFI	Arizona	3
	California	3
	Kentucky	1
	Maryland	3
	Michigan	1
	New Jersey	3
	Ohio	1
	Oregon	5
	Pennsylvania	1
	Vermont	1
	West Virginia	1

[a]Overturned in April 1983 by Fifth Circuit Court of Appeals.

[b]Ban pertains only to use in state licensed buildings.

[c]Product removed from list of approved building materials.

[d]Product removed from specifications for bids on low cost housing.

SOURCES:

1. Consumer Products Safety Commission (CPSC), 1983. "Ban of Urea-Formaldehyde Foam Insulation, Withdrawal of Proposed Information Labeling Fule, and Denial of Petition to Issue a Standard." Federal Register. v. 47. No. 64. p. 14368.

2. Personal communication with Connie Smercek, Save Us From Formaldehyde Environmental Repercussions (SUFFER), August 29, 1984.

3. Consumer Products Safety Commission (CPSC), 1980. "Urea-Formaldehyde Foam Insulation; Proposed Notice to Purchasers." Federal Register. v. 45. No. 113. pp. 39435, 39441.

4. The UFFI Centre, 1983. The UFFI (Urea-Formaldehyde Foam Insulation) File. Information packet published by Consumer and Corporate Affairs Canada. pp. 17-38.

5. Personal communication with Dr. Leslie P. Williams, Department of Disease Monitoring and Control, Oregon Department of Health, May 25, 1984.

Canada and Israel are two foreign countries known to have bans on UFFI. In Canada, the product was banned by the Minister of Health and Welfare in 1980. This ban faced court challenges, but was upheld in 1981 (UFFI Centre, 1982).

5.1.5 Information Disclosure Requirements

The previous policies use the police powers of government in an attempt to dictate the behavior of producers or consumers. An alternative approach is to make limited use of the police powers and only require producers to provide information on the health consequences of their products. Consumers, now more fully informed, may evaluate the potential health risks and product cost against the utility they would enjoy and make their own decision on the appropriateness of the product for them. Requirements to disclose the possible health effects of UFFI and other products containing formaldehyde have been established by a number of governmental entities in the United States (see Table 5-9).

In 1979, DOE proposed a printed warning to be issued by manufacturers to purchasers of UFFI stipulating specific symptoms of formaldehyde exposure and their potential duration (CPSC, 1980). In 1980, the CPSC proposed a requirement on manufacturers to give specific performance and technical information to purchasers of UFFI, and to alert them to possible ill effects of the use of the foam (CPSC, 1980). However, the proposal was withdrawn in 1982 after the CPSC decided that such information disclosure would not provide enough protection from formaldehyde exposure (CPSC, 1982).

The FDA requires package labelling for cosmetics of the ingredients listed in descending order of predominance. This label must "appear with such prominence and conspicuousness as to render it likely to be read and understood by ordinary individuals under normal conditions of purchase" (CIR, 1984). In the case of nail hardeners, the FDA requires the package to furnish instructions for safe use and warnings of possible adverse health consequences. The EEC requires cosmetic product labels to list formaldehyde and paraformaldehyde as ingredients when the concentration of either in the product exceeds 0.05 percent (CIR, 1984).

TABLE 5-9. INFORMATION DISCLOSURE REQUIREMENTS

Regulatory action	Government or agency adopting	Reference
Product labeling and/or disclosure requirements of possible adverse health effects of UFFI	U.S. Department of Energy (DOE)[a]	1
	U.S. Consumer Product Safety Commission (CPSC)[b]	1
	Connecticut	1
	Maine	2
	Minnesota	2
	New Hampshire	2
	New York	2
	Rhode Island	2
	Denver, Colorado	2
of formaldehyde in cosmetics	U.S. Food and Drug Administration (FDA)[c]	3
	European Economic Community (EEC)[d]	3
of formaldehyde in wood products	New Hampshire[e]	4
Government-issued warning on possible adverse health effects of UFFI	Colorado	1
	Virginia	1

[a]Material and foam installation standards for UFFI proposed under Residential Conservation Program.

[b]Standards proposed under Section 27(e) of the Consumer Product Safety Act.

[c]Requires listing of ingredients on label in descending order of predominance in product.

[d]Requires listing of formaldehyde and paraformaldehyde as ingredients when concentrations of either exceed 0.05%.

[e]Label indicates formaldehyde is contained in the product.

SOURCES: 1. Consumer Products Safety Commission (CPSC), 1980. "Urea-Formaldehyde Foam Insulation; Proposed Notice to Purchasers." Federal Register. v. 45. No. 113. pp. 39435, 39441.

2. Consumer Products Safety Commission (CPSC), 1983. "Ban on Urea-Formaldehyde Foam Insulation, Withdrawal of Proposed Information Labeling Rule, and Denial of Petition to Issue a Standard." Federal Register. v. 47. No. 64. p. 14368.

3. Cosmetic Ingredient Review, 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology. v. 3. No. 3. pp. 161-162.

4. Telecom, 1984. Telephone communication with John Stanton of the New Hampshire Bureau of Environmental Health regarding monitored levels of formaldehyde concentrations in nonoccupational settings in New Hampshire, and state legislation regarding formaldehyde. May 29, 1984.

Government-issued warnings have been undertaken in Colorado and Virginia. In Colorado, the Attorney General's Office published a warning in 1978 with respect to formaldehyde and suspected high-risk groups. The warning suggested that pregnant women, infants, young children, the elderly, the sick, and anyone previously sensitized or with a history of respiratory problems avoid exposure to formaldehyde vapors when possible (Small, 1982).

Six other states have required producers to label or verbally disclose the possible adverse health effects of UFFI. New Hampshire requires labelling of wood products as to their formaldehyde content (see Table 5-9).

5.1.6 Compensation Schemes

In addition to policies designed to reduce exposures to formaldehyde, governments have also considered and in some cases implemented programs to compensate homeowners who installed UFFI (see Table 5-10). Two countries and the Commonwealth of Massachusetts require repurchase or compensation for persons having UFFI in their homes.

Canada has the most comprehensive national program. All UFFI homeowners (including detached, semi-detached, row, duplex, triplex, and pre-fabricated housing, condominiums, and mobile homes on a permanent foundation) are eligible to receive technical information from the governmant, including testing for formaldehyde levels before and after UFFI removal, and financial assistance up to $5,000 for "costs incurred in implementing corrective measures" (UFFI Centre, 1983). The government's Canadian Home Insulation Program (CHIP) provides funds to cover the cost of removal of UFFI and replacement with another insulation for those homes which exceed $5,000. The labor is provided free or at reduced cost, from the New Employment Expansion and Development (NEED) program, a job creation program designed to offer employment for those whose unemployment insurance benefits are exhausted, to participatants in the CHIP or UFFI programs.

Programs in the Netherlands and Massachusetts require the supplier or the installer of the UFFI, rather than the government, to pay for removal of the insulation. In the Netherlands, homes which test above the official 0.1 ppm standard for residences are eligible for UFFI removal paid for by the applicator of the foam (UFFI Centre, 1983).

TABLE 5-10. COMPENSATION SCHEMES

Regulatory action	Government adopting	Reference
Repurchase requirements	Canada[a]	1
	Netherlands[b]	1
	Massachusetts[c]	2

[a]Canadian government funds removal. There is no need to prove adverse health effects to qualify for repurchase.

[b]Applicator of foam funds removal if structure tests above 0.1 ppm standard.

[c]If identified, supplier of foam pays for removal. There is no need to prove adverse health effects to qualify for repurchase.

SOURCES: 1. The UFFI Centre, 1983. The UFFI (Urea-Formaldehyde Foam Insulation) File. Information packet published by Consumer and Corporate Affairs Canada. pp. 17-38.

2. Massachusetts Department of Public Health, 1984. "Fact Sheet - UFFI Repurchase Regulations." Boston, Massachusetts.

Massachusetts enacted repurchase legislation in 1980. After suspension due to a court challenge, the requirement was upheld by the Massachusetts Supreme Judicial Court in April, 1983. According to the regulation, any owner of a UFFI-insulated building is permitted to make a request through the Department of Public Health for removal of the insulation and for restoration of the building at the expense of the supplier of the insulation (Massachusetts Department of Public Health, 1984). The owner is required to provide the names of suppliers involved to qualify for a Certificate of Right to Repurchase, which legally requires the supplier to fund the removal of UFFI and restoration of the home. Lower level suppliers may be reimbursed for the costs incurred by suppliers farther up the distribution chain, so that the final responsibility rests with the manufacturer. The Massachusetts Department of Public Health estimated that approximately 250 requests filed between 1980 and 1982 were pending under this legislation, and more were expected in 1984 (Massachusetts Department of Public Health, 1984).

5.2 PRIVATE SECTOR RESPONSES

The publicity generated by government actions to reduce population exposure to formaldehyde, particularly the UFFI bans, has resulted in heightened awareness of potential health problems associated with formaldehyde, according to State Public Health officials, realtors, and appraisers contacted by telephone. A variety of responses on the part of the private sector have been observed. They include:

- Tort litigation
- Public awareness programs
- Disclosure of UFFI and appraisal of effects of UFFI on house values
- Testing programs
- Removal or neutralization of UFFI
- Changes in production processes.

These actions are outlined in Table 5-11 and discussed in the following sections.

TABLE 5-11. NONGOVERNMENTAL RESPONSES TO FORMALDEHYDE EXPOSURE

Action	Groups involved	Purpose of action
Tort litigation	Persons living with and being affected by formaldehyde in the home	Compensation for injury and economic loss from property damage
Public awareness programs	Citizen groups for education (SUFFER[a]) and activism (CERTS[b])	Education about the potential problems of formaldehyde and solutions to those problems
	Industry groups for research and education (Formaldehyde Institute, Cosmetic Ingredient Review Expert Panel)	Standards recommendations Research on formaldehyde problems and use in products
Disclosure of UFFI presence in homes	Many State realtors' associations	Avoidance of liability for health hazards of formaldehyde exposure
Differential appraisal values for homes with UFFI	Many appraisal firms during CPSC ban	Avoidance of liability for health hazards of formaldehyde exposure
Testing for formaldehyde levels in homes	Persons experiencing exposure symptoms (usually recommended by State public health department)	Identification of possible cause of symptoms
	Persons wishing to sell a home containing UFFI (usually recommended by realtor)	Reassurance for buyer that formaldehyde level is not harmful
Treatments for removal or neutralization of UFFI	Persons experiencing exposure symptoms or fearful of future harm from exposure	Relief of symptoms or protection from potential symptoms
	Persons wishing to sell a home containing UFFI	Protection from market devaluation due to presence of UFFI
Changes in production technology to reduce formaldehyde exposure	Some industries using large amounts of formaldehyde	Protection of workers from formaldehyde exposure Protection from future liability due to worker and consumer exposure

[a]Save Us From Formaldehyde Environmental Repercussions.

[b]Citizens Engaged in Removal of Toxic Substances.

5.2.1 Tort Litigation

Tort litigation is an option chiefly exercised by persons exposed to formaldehyde from the offgassing of products in the home. The most well-known product is UFFI, but other materials used in home constructions, such as pressed wood products, may be candidates for tort litigation.

Hundreds of suits have been filed against manufacturers and installers claiming injury to persons or property from formaldehyde (Dworkin and Mallor, 1983). A Minneapolis law firm which operates a clearinghouse for attorneys representing formaldehyde victims estimates that there are approximately 700 lawsuits pending in addition to a $2 billion class action suit filed on behalf of 70,000 to 130,000 New York residents (Lewin, 1982). Hundreds of lawsuits were filed even before the CPSC ban on UFFI (Dworkin and Mallor, 1983). Some insurers are concerned that UFFI claims may equal or even exceed the number of asbestos claims in the near future (Mika, 1983).

Some awards in formaldehyde lawsuits have been substantial. Several cases resulted in awards for more than $200,000 (Lewin, 1982). Mobile home owners who sued over formaldehyde harms have been awarded replacement costs for the homes (Chemical Week, 1982; Dworkin and Mallor, 1983). Estimates of costs of removal of the UFFI and installation of alternative insulation range from $6,000 to $20,000 per home (Smith, 1982; Massachusetts Office of Consumer Affairs, n.d.). If each owner of the estimated 500,000 homes containing UFFI were granted only these damages, the potential total liability could be as high as $10 billion (Johnson, 1983).

Recovery of damages may, however, be difficult in light of the UFFI industry structure. Many of the manufacturers and installers who are responsible for the UFFI in homes are small operators, and have inadequate insurance to pay for large awards to consumers. Some speculation has arisen that companies will follow the lead of asbestos-related businesses and file for bankruptcy (Dworkin and Mallor, 1983).

The industry was declining even before the CPSC ban, as adverse publicity and better substitute insulations radically reduced the demand for UFFI (Chemical Week, 1983). From an estimated 34 UFFI manufacturers in 1977, the number dropped to six in 1982 by one estimate (Chemical Week, 1982) and to four by another (Smith, 1982). Dworkin and Mallor (1983) stated that no UFFI manufacturers were in operation by 1983. Estimates of the number of installers have gone from more than 500 in 1977 to as few as 200 in 1981 (Smith, 1982).

5.2.2 Public Awareness Programs

Both citizen and industry groups have been formed in the wake of the formaldehyde controversy. The Save Us From Formaldehyde Environmental Repercussions (SUFFER) group is composed of individuals, health professionals and attorneys who seek to educate health and legal professionals concerning formaldehyde problems. SUFFER was founded in 1980 and has 50 state groups with 1000 members.

The Citizens Engaged in Removal of Toxic Substances (CERTS) group is based in Michigan. This organization is primarily a legal activist group which lobbies for changes in legislation to reduce the likelihood of exposure to substances like formaldehyde.

Industry organizations such as the Formaldehyde Institute, founded in 1979, primarily exist to conduct research on potential health effects resulting from exposure to formaldehyde and formaldehyde products and appropriate means of control. The Formaldehyde Institute is affiliated with the Synthetic Organic Chemical Manufacturers Association and provides a medium of communication between industry members and government agencies.

Such organizations as the Cosmetic Ingredient Review Expert Panel, the American Society of Heating, Refrigeration, and Air Conditioning Engineers, and the American Conference of Governmental Industrial Hygienists perform a quasi-governmental role. They study various aspects of the formaldehyde problem such as toxicology of particular products and means to reduce indoor exposures, and propose standards for governmental adoption. These groups bring special expertise to the study of particular aspects of the formaldehyde issue.

Other industry groups involved in the formaldehyde problem are directed toward specific product groups. The Formaldehyde Task Force Fund, founded in 1979, is composed of hardwood plywood and veneer manufacturers and hardwood plywood prefinishers. It concentrates on production processes and testing and labeling of formaldehyde-containing products. The Hardwood

Plywood Manufacturers Association conducts tests on a variety of products related to hardwood plywood, of which formaldehyde is one. The results are then publicized. The Forest Products Safety conference and the National Particleboard Association are concerned with safety standards and other regulations in their respective production processes.

5.2.3 Disclosure and Appraisal of UFFI in Homes

The adverse publicity about formaldehyde exposure, and about UFFI in particular, has had an impact on both real estate agents and appraisers. The CPSC ban not only heightened public awareness, but also raised the prospect of liability lawsuits against realtors, appraisers, and lenders (Savings and Loan News, 1983).

Appraisers and lenders addressed the potential litigation resulting from failure to correctly value homes containing UFFI, and from failure to identify the presence of UFFI in the property. Since removal of UFFI and replacement with another insulating material may not always solve irritation and sensitization problems, it was recommended that merely devaluing a home by the cost of such a procedure is inadequate for legal protection (Savings and Loan News, 1983).

Revealing the existence of UFFI to the buyer would not afford legal protection to appraisers. If undervalued, from the perspective that the buyer experiences no health problems or is apathetic to the presence of the UFFI, the seller of the home could sue the appraiser for the difference in value assessed to the UFFI (Savings and Loan News, 1983; Runzheimer Reports on Relocation, 1983). The confusion over proper valuation would require toxicological opinions and timely comparable sales data for resolution (Savings and Loan News, 1983).

Appraisers eager to shift detection responsibility from themselves proposed a qualification to each appraisal report which warned that the appraisal should become null and void if UFFI were discovered on the premises (Savings and Loan News, 1983). Special loans were suggested for UFFI properties, with hold-harmless releases to protect lenders and appraisers in the event that the buyer experienced symptoms related to formaldehyde exposure (Savings and Loan News, 1983). There are some instances in which mortgage loans were simply not extended to homes containing UFFI during the period of the CPSC ban. In Wisconsin, legislation was enacted to provide for inspection of properties for UFFI, as well as other structural problems.

During the duration of the CPSC ban, conferences and meetings for discussion of potential UFFI liability were common among appraisers. The overturn of the ban reduced, if not eliminated, concern for liability on the part of appraisers. The overturn was apparently perceived as a statement that no real harm from formaldehyde exposure could be proved, and so liability for failure to reveal or correctly value a defect (UFFI) in a structure no longer existed.

The effects of publicity for real estate brokers have been more long-lasting. Realtors also feared liability for selling homes containing UFFI to unsuspecting buyers. Realtors aimed at reducing their legal responsibility by increasing the awareness of the presence of UFFI among potential buyers and sellers. They hoped that proof that both parties had this knowledge prior to the sale of a home would reduce the chance of later lawsuits.

The National Association of Realtors was aggressively involved in the hearing process before the CPSC regarding the ban on UFFI. The Association supported disclosure requirements to fend off lawsuits. Many State Realtors' Boards adopted disclosure requirements, providing forms for both the buyer and seller to sign acknowledging their awareness of the presence of UFFI in the home (Savings and Loan News, 1983; Oregon Association of Realtors, n.d. a and b). In some states, the UFFI designation is included on the multiple listing forms filed with the State Boards.

In Massachusetts, brokers are advised to check for UFFI in homes they list and are coached on identification of insulation as UFFI (Massachusetts Office of Consumer Affairs, n.d.). This information helps realtors to ascertain the presence of UFFI in homes where the seller is unwilling to provide such information.

During the CPSC ban, brokers were warned to allow only appraisers to assess the value of homes containing UFFI to further protect themselves from responsibility in the event of a lawsuit (Savings and Loan News, 1983). This action shifted the burden back onto appraisers to determine the effect of the UFFI on the value of the home.

Real estate agents continue to practice disclosure in many states, despite the overturn of the UFFI ban. In effect, the public concern for health effects of formaldehyde has prompted this action, since the threat of lawsuits for failure to disclose has somewhat diminished since the court decision.

5.2.4 Testing Programs

Testing for formaldehyde levels is usually undertaken for two reasons. One is to identify formaldehyde as the cause of symptoms experienced by persons in homes or offices. The other is to reassure buyers of homes containing UFFI that the formaldehyde levels are not high enough to cause adverse health effects.

In the first case, testing is usually recommended by a State Public Health official after complaints of symptoms are made, and formaldehyde is identified as a possible source of the problems. Conversations with State Public Health officials in New Jersey, Connecticut, Wisconsin, and Oregon indicate that the demand for testing has been high. In most cases, symptoms were experienced by those who requested information.

Realtors in many states recommend testing of homes containing UFFI to protect all parties to the transaction. The real estate agent and the seller are relieved of some fear of lawsuit for damages and the buyer is made more certain that adverse health consequences from occupation of the home are not likely to result.

The tests are performed by several methods, some more sensitive than others. A previously widely used test is the Drager method, sensitive only to levels above 0.5 ppm. A more reliable test utilizes a chromatographic impinger. A self-testing kit being marketed for home use is the 3-M Monitor which gives results approximately 66 percent lower than the chromatographic impinger, according to Connie Smercek, of SUFFER (Telcom, 1984b).

The costs of the tests vary. Among eight laboratories referenced by the Connecticut Department of Health, prices range from $25 to $90 per sample, plus travel expenses of the technician. At Bennett Laboratories in Washington, costs for technician testing are $50 per sample (plus travel) with testing recommended in two to three rooms, and in the ambient environment (Telecom, 1984a). Bennett Laboratories also markets a self-testing kit for $50 which includes a laboratory analysis of the formaldehyde levels detected.

Despite the peace of mind offered by these tests, some agencies feel that there is no "safe" level of formaldehyde. The CPSC made such an attitude clear in its proposal to ban UFFI (CPSC, 1982). The Massachusetts Office of Consumer Affairs also adopts this position (Massachusetts Office of Consumer Affairs, n.d.).

5.2.5 Treatments to Reduce UFFI Exposure

When testing reveals "excessive" levels of formaldehyde, usually considered either higher than ambient or above a level of 0.1 ppm, the standard recommended by ASHRAE, some remedial measures to reduce formaldehyde exposure may be taken. Persons who experience symptoms of exposure often prefer to undertake some treatments to their homes, regardless of the levels of formaldehyde tested. Nonhealth problems due to the reaction of UFFI with the climate may include buckling of walls, exterior paint peeling, damage to pipes in walls, deterioration of mortar, wood rot, and growth of fungus (Thun et al., 1982; UFFI Centre, 1983). Attempts are also made to prevent these structural problems through treatment of the UFFI.

A variety of treatments to the structure containing UFFI have been tried. These include use of caulking compounds and vapor barriers to reduce humidity reaching the UFFI, chemical absorption filters to remove the formaldehyde from the air, increased ventilation to force formaldehyde out of the home and to prevent buildup of moisture in the home, cleaning of interior surfaces and airing out furniture to remove formaldehyde which may be "clinging" to the interior of the home, and fumigation with "organic" substances such as vegetable roots and leaves or coffee grounds and with ammonia solutions to trap the formaldehyde fumes (Bowen et al., 1981; Massachusetts Office of Consumer Affairs, n.d.; UFFI Centre, 1983; Small, 1982; Geomet, Inc., and Technology and Economics, Inc., 1980). These remedies have proved ineffective in many, if not most, cases (Telecom, 1984a; Massachusetts Office of Consumer Affairs, n.d.).

Removal of the UFFI and treatment of the cavity with sodium bisulfate are considered to be the only permanent solution to the offgassing problem by many (Small, 1982; Massachusetts Office of Consumer Affairs, n.d.).

These methods have been used in Canada to achieve formaldehyde levels in indoor air comparable to ambient levels (Bowen et al., 1981; UFFI Centre, 1983). The cost of such a treatment may be prohibitive since removal of either an interior or an exterior wall is necessary. Costs range from $6,000 to $20,000 per home to complete the treatment and install another type of insulation (Smith, 1982; Massachusetts Office of Consumer Affairs, n.d.).

Removal of the UFFI without dismantling walls has been attempted in Canada. Some methods include mechanical vibration, compressed air jet applications, steam soak followed by steam jet, and hot air soak followed by air jet (UFFI Centre, 1983). The efficacy of these techniques is not completely known. It has been noted that elevated formaldehyde concentration may continue even after removal of the insulation if treatment of the cavity is not performed. These methods do not allow the same measure of post-removal treatment as does a removal procedure which includes dismantling of walls.

Treatments of the UFFI in situ have been devised in an attempt to remedy the offgassing at a lower cost than complete removal. Ammonia compounds have been used for this purpose in Canada, the United Kingdom, and the Netherlands (UFFI Centre, 1983; Telecom, 1984a). However, this chemical may also cause problems because of its reactivity with copper, which affects copper wiring and brass fixtures (Telecom, 1984a).

One procedure used by Controls for Environmental Pollution, Inc. of Sante Fe, New Mexico is a pressurization technique to accelerate offgassing (Johnson, 1983). The estimated half-life of offgassing in UFFI averages 4.4 years (National Research Council, 1981), with even greater decreases in formaldehyde levels noted after 5 years (Versar, 1982; Telecom, 1984c). Under the procedure, a structure is subjected to extreme interior-air pressure and temperatures around 95 degrees Farenheit, to simulate the offgassing which occurs in the first half-life,or longer. When temperature and air pressure are restored to normal, formaldehyde levels in the structure are lowered because the formaldehyde content of the product is lower.

A technique developed by Bennett Laboratories of Tacoma, Washington treats UFFI with a carrier gas, the active ingredient of which is anhydrous ammonia, to neutralize the acid catalyst which causes the chemical breakdown leading to offgassing of formaldehyde (Telecom, 1984a). The company offers a 10-year warranty that formaldehyde concentrations in the treated home will be no greater than 0.05 ppm above ambient levels. The process, costing $1.50 to $2.00 per square foot of floorspace, has proved popular among those persons who wish to place their UFFI homes on the market and anticipate buyer resistance to the UFFI.

5.2.6 Changes in Production Processes Using Formaldehyde

Recognition of worker and consumer health problems due to formaldehyde has lead to altered production technologies to reduce formaldehyde exposure. Table 5-12 outlines the options available to industry groups.

5.2.6.1 Formaldehyde and Formaldehyde-Based Compound Production--

These industries prepare primary and intermediate products for use by other industries. As such, reduction in production of actual quantities of urea-formaldehyde are unlikely, unless demand characteristics of the market change. Control options in these industries focus on providing better protection for workers through increased ventilation and better systems of checking and repairing leaks in ventilation systems.

5.2.6.2 Particleboard and Plywood Manufacture--

Particleboard and plywood manufacture are industries which represent some of the highest exposure levels for workers (Versar, 1982). This fact has been recognized in the industry. As early as 1971, attention was being directed to problems experienced by workers exposed to formaldehyde (Freeman and Grendon, 1971). Weyerhaeuser determined that formaldehyde levels greater than 0.8 ppm were unsuitable, and effected use of "low odor" binders in its glued and laminated wood plants (Freeman and Grendon, 1971).

Responses available to these industries include methods that reduce use of urea-formaldehyde resins (by using substitutes, by using resins with less free formaldehyde, or by using non-formaldehyde resins), methods which limit the offgassing of formaldehyde (by using additives or treatments which block emissions), provisions of better ventilation in work areas, and prolonged storage to allow offgassing prior to distribution. Evaluations of cost and feasibility will depend on the individual company attempting to institute the new techniques (Geomet, Inc., and Technology and Economics, Inc., 1980).

Major producers of pressed wood products such as Weyerhaeuser and Georgia-Pacific assert that use of "low-odor" formaldehyde has reduced formaldehyde levels in plants to less than 0.1 ppm (Business Week, 1981; Telecom, 1984d). The National Particleboard Association and Hardwood Plywood Manufacturers Association claim that airborne formaldehyde in plants has been reduced by 60 percent to 70 percent (Business Week, 1981).

Reductions in the formaldehyde levels associated with the products are of concern to consumers. Technologies already in use have reduced vapor release by 65 percent to 95 percent (Wynn, 1983). At least one lumber manufacturer now produces a plywood product which is guaranteed to be free of urea-formaldehyde resin (Telecom, 1984c). However, because these products are sold in "lots," a retailer may have materials from several different sources. This makes industry-wide control difficult to establish, since not all producers use the "low-odor" processes (Telecom, 1984d).

5.2.6.3 Textile Finishing--

Formaldehyde compounds impart permanent press properties to textiles. All these compounds have potential for offgassing (Wayland et al., 1981). Release of formaldehyde occurs in the finishing plants during application, in storage areas, in cutting rooms, and in retail stores (Reeves, et al., 1981; Andrews et al., 1980). The textile industry, as a whole, has made progress in recognizing the problems associated with formaldehyde use, in performing research directed in solving these problems, and in instituting the solutions. Despite these efforts, exposures remain fairly high because of the pervasiveness of formaldehyde throughout the entire production process (Versar, 1982).

Alterations in the production process may be made through changes in the timing and temperature of the curing stage, treatment agent concentration, catalyst-to-agent ratio, fabric, catalyst, and other aspects of the finishing process (Andrews et al., 1980; Wayland et al. 1981). Reductions in agent concentrations and increases in catalyst-to-agent ratios mean that formaldehyde is a smaller component in the treatment solution. Substitutes eliminating formaldehyde have been found deficient, so much research has concentrated on developing chemicals which have enhanced resistance to vapor release (Wayland et al., 1981; Reeves et al., 1981).

Various experiments have been conducted on the finishing process. These have provided alternative control options. Curing may be attempted under different temperatures (Reeves et al., 1981). Fabrics may be bathed after permanent press treatments to remove free formaldehyde (Reeves et al., 1981). Gaseous treatments compare very favorably with other types of treatments in terms of both initial formaldehyde concentrations and release of formaldehyde with washing (Reeves et al., 1981). Scavengers (molecules which bind the free formaldehyde) are added to the fabric, so that a reduction in vapor release occurs during finising, but an increase in release from treated fabric is observed (Reeves et al., 1981).

Storing fabrics in areas with increased ventilation permits offgassing to occur before use in intermediate production and final consumption of a garment.

5.2.6.4 Paper Manufacture--

Substitutes such as melamine resins for urea-formaldehyde resins are recommended in paper manufacture. However, melamine substitutes are much more costly to use than are urea-formaldehydes (Youngquist, 1981). Reduction of free formaldehyde levels in treatments is another alternative to control of formaldehyde exposure in paper manufacture.

"Wet-strength additives" are acceptable resins which contain no formaldehyde. However, undesirable properties, such as embrittlement, reduced absorbancy, and a harsh feel are associated with use of such additives as polyamide resins (Oatway and Klemm, 1981).

5.2.6.5 Embalming--

Formaldehyde has been an important chemical in the embalming and preserving industry due to its disinfecting and preserving properties. Additives such as germicides, preservatives, dispersing and wetting agents, anticoagulants, red dyes, and perfumes are commonly contained in commercial preparations (Oatway and Klemm, 1981).

Feasible alternatives to reducing this exposure include increasing ventilation in embalming laboratories and using non-formaldehyde embalming fluids. Use of suggested substitutes is not only expensive, but toxicologically uncertain. Substitution may entail merely a tradeoff of one exposure harm for another (Oatway and Klemm, 1981).

5.2.6.6 Industrial Coatings--

The production of a coated product, such as wood furniture or appliances coated with baked enamel, consists of both a coating formulation process and an application process (Oatway and Klemm, 1981). Reduction of free formaldehyde levels in resins may be accomplished by use of 100 percent solid resins and powdered resins, in which free formaldehyde is completely driven off during the drying process (Oatway and Klemm, 1981). This process reduces the exposure of the product consumer.

Reduction of formaldehyde exposure for the worker may be achieved by increased ventilation in spray booths where the coatings are applied, and by airless or electrostatic application techniques. These latter methods reduce the amount of overspray, so that less free formaldehyde is in the air (Oatway and Klemm, 1981).

5.2.6.7 Urea-Formaldehyde Foam Insulation--

Though techniques exist for reduction of formaldehyde exposure through product modification, the effectiveness under the many climatic conditions to which the insulation is exposed is questionable (see Section 5.1.1). Under current market conditions, it is unlikely that either control option suggested in Table 5-12 will be extensively used in the United States.

Scavengers may reduce exposure to both the installer and the consumer, but improper applications and mixing of the insulation may undermine effectiveness of this option (Oatway and Klemm, 1981). Use of modified products in Spain and Switzerland has had some success in reducing the number of complaints about problems with the insulation (see Section 5.1.2).

5.2.6.8 Mildew Preventatives--

Mildew preventatives contain paraformaldehyde to inhibit mildew growth. They are used extensively in the southeastern United States (Oatway and Klemm, 1981).

Substitution of other chemicals for this purpose is a questionable solution because of the potential adverse health effects which may be

TABLE 5-12. INDUSTRY CONTROL OPTIONS TO REDUCE WORKER AND CONSUMER FORMALDEHYDE EXPOSURE

Industry	Control option	Reference
Formaldehyde and resin production	Use vent scrubber to control storage and handling emissions	1
	Institute leak detection and repair programs	1
Formaldehyde-based compound production	Improve local exhaust ventilation in reactor charging/sampling ports and in drum-filling stations	1
	Institute leak detection and repair programs	1
Particleboard and plywood manufacture	Use resins containing less free formaldehyde	2, 3, 4
	Use phenolic resins instead of urea-formaldehyde resins	1, 2, 4
	Store particleboard or plywood prior to distribution	1, 4
	Treat particleboard or plywood with ammonia or laminate	1, 2, 3, 4
	Use adhesives which do not contain formaldehyde resins	1, 3
	Equip production areas with exhaust systems	3
	Use flour, potato starch, melamine and lignosulphonates as additives	2
Textile finishing	Use resins which leave little residual formaldehyde	1, 4, 5, 6
	Use formaldehyde scavengers to bind with free formaldehyde	1, 6
	Include after-wash step in finishing	1, 4, 6
	Increase ventilation in storage and production stages	1, 4
	Use gaseous treatment instead of liquid treatment in finishing	6
Paper manufacture	Reduce free formaldehyde resins	1
	Use "wet-strength additives", such as polyamide resins	1
	Use melamine resins as a substitute for urea-formaldehyde resins	1
Embalming	Increase ventilation in embalming lab	1
	Use non-formaldehyde embalming fluids	1

(continued)

TABLE 5-12 (continued)

Industry	Control Option	Reference
Industrial coatings	Reduce free formaldehyde levels in resins	1
	Increase ventilation in spray booths	1
	Use application techniques resulting in lower emissions	1
Urea-formaldehyde foam insulation	Reduce free formaldehyde levels in resins	1
	Use formaldehyde scavengers	1
Mildew preventatives	Product substitute mildewcides	1
	Use low wattage heaters	
Automotive manufacture	Produce catalytic converters and other hydrocarbon control devices	1

SOURCES: 1. Oatway, Janet, and Hans A. Klemm, 1981. Formaldehyde Regulatory Control Options Analysis. Draft Final Report. Contract No. 68-01-5960. Prepared for Office of Chemical Control, Environmental Protection Agency. Report No. GCA-TR-81-1-G. Bedford, Massachusetts: GCA Corporation.

2. Geomet, Inc., and Technology and Economics, Inc., 1980. An Evaluation of Formaldehyde Problems in Residential Mobile Homes. Final Task I Report. Contract No. H-5105. Prepared for Office of Policy Development and Research, Department of Housing and Urban Development.

3. Niemelä, Raimo, and Harri Vainio, 1981. "Formaldehyde Exposure in Work and the General Environment." Scandinavian Journal of Work and Environmental Health. 7:95-100.

4. Environmental Protection Agency (EPA), 1984. "Formaldehyde; Determination of Significant Risk; Advance Notice of Proposed Rulemaking and Notice." Federal Register. 49(101):21869-21898.

5. Andrews, B. A. Kottes, R. J. Harper, Jr., and Sidney L. Vail, 1980. "Variables That Influence Formaldehyde Release from Cottons Finished for Durable Press." Textile Research Journal. 50:315-322.

6. Reeves, Wilson A., Mary O. Day, K. Rinn McLellan, Tyrone L. Vigo, 1981. "Formaldehyde Release in Formaldehyde- and Resin-Finished Fabrics." Textile Research Journal. 51(7):481-485.

associated with these alternatives. Low wattage heaters may be employed to dry out areas making them less hospitable to mildew growth (Oatway and Klemm, 1981).

5.2.6.9 Automotive Manufacture--

Transportation vehicles contribute substantially to formaldehyde levels in ambient air, particularly in metropolitan areas (NRC, 1981). Formaldehyde emission rates for older, noncatalytic conversion engines are three to six times those of catalytic converters (Oatway and Klemm, 1981).

Reduction of hydrocarbon emissions directly reduces formaldehyde emissions. Increased use of the catalytic converters and other modifications which reduce hydrocarbon emissions will result in enhanced consumer protection (Oatway and Klemm, 1981).

5.3 REFERENCES

Andrews, B. A. Kottes, R. J. Harper, Jr., and Sidney L. Vail, 1980. "Variables That Influence Formaldehyde Release From Cottons Finished for Durable Press." Textile Research Journal 50:315-322.

Ashford, Nicholas A., C. William Ryan, and Charles C. Caldart, 1983. "A Hard Look at Federal Regulation of Formaldehyde: A Departure from Reasoned Decisionmaking." Harvard Environmental Law Review 7:297-370.

Bernstein, Robert S., Henry Falk, Douglas R. Turner, and James M. Melius, 1984. "Nonoccupational Exposures to Indoor Air Pollutants: A Survey of State Programs and Practices." American Journal of Public Health 74(9):1020-1023.

Bowen, R. P., C. J. Shirtliffe, and G. A. Chown, 1981. Urea-Formaldehyde Foam Insulation: Problem Identification and Remedial Measures for Wood-Frame Construction. Building Practice Note No. 23. Ottawa, Canada: Division of Building Research, National Research Council of Canada.

Business Week, 1981. "A Letup in the Drive to Regulate Formaldehyde." (2709):88.

Chemical Week, 1982. "Urea-Formaldehyde Foam Gets the Axe for Home Insulation." 130(9):12-13.

Consumer Product Safety Commission (CPSC), 1982. "Ban of Urea-Formaldehyde Foam Insulation, Withdrawal of Proposed Information Labeling Rule, and Denial of Petition to Issue a Standard." Federal Register 47(64):14365-14419.

Consumer Product Safety Commission (CPSC), 1980. "Urea-Formaldehyde Foam Insulation; Proposed Notice to Purchasers." Federal Register 45(113):39433-39444.

Cosmetic Ingredient Review (CIR), 1984. "Final Report on the Safety Assessment of Formaldehyde." Journal of the American College of Toxicology 3(3):157-184.

Dally, Kay A., Lawrence P. Hanrahan, Mary Ann Woodbury, and Marty S. Kanarek, 1981. "Formaldehyde Exposure in Nonoccupational Environments." Archives of Environmental Health 36(6):277-284.

Dworkin, Terry Morehead, and Jane P. Mallor, 1983. "Liability for Formaldehyde-Contaminated Housing Materials: Toxic Torts in the Home." American Business Law Journal 21(3):307-334.

Environmental Protection Agency (EPA), 1984. "Formaldehyde; Determination of Significant Risk; Advance Notice of Proposed Rulemaking and Notice." Federal Register 49(101):21870-21898.

Federal Panel on Formaldehyde, 1982. "Report on the Federal Panel on Formaldehyde." Environmental Health Perspectives 43:139-168.

Freeman, H. G., and W. C. Grendon, 1971. "Formaldehyde Detection and Control in the Wood Industry." Forest Products Journal 21(9):54-57.

Gammage, R. B., 1981. Final Report to the Canadian Department of Consumer and Corporate Affairs: Product Safety Branch. Report No. DOE/NBM-2020919. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Gammage, R. B., B. E. Hingerty, Thomas G. Matthews, Alan R. Hawthorne, Don R. Womack, Rita R. Westley, and Kailish C. Gupta, 1983. Temporal Fluctuations of Formaldehyde Levels Inside Residences. Report No. DE 83009788. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Geomet, Inc., and Technology and Economics, Inc., 1980. An Evaluation of Formaldehyde Problems in Residential Mobile Homes. Final Task I Report. Contract No. H-5105. Prepared for Office of Policy Development and Research, Department of Housing and Urban Development.

Hattis, Dale, Clifford Mitchell, Janet McCleary-Jones, and Nancy Gorelick, 1981. Control of Occupational Exposures to Formaldehyde: A Case Study of Methodology for Assessing the Health and Economic Impacts of OSHA Health Standards. Report No. CPA-81-17. Cambridge, Massachusetts: Center for Policy Alternatives, Massachusetts Institute of Technology.

Hawthorne, A. R., R. B. Gammage, C. S. Dudney, D. R. Womack, S. A. Morris, R. R. Westley, and K. C. Gupta, 1983. Preliminary Results of a Forty-Home Indoor-Air-Polution Monitoring Study. Oak Ridge, Tennessee: Oak Ridge National Laboratory.

Johnson, Greg, 1983. "Air Pollution, the 'Inside' Story." Industry Week. 217(3):44-50.

Lewin, Tamar, 1982. "Insulation Lawsuits Abound." New York Times. May 25, 1982. pp. D1, D7.

Massachusetts Department of Public Health, 1984. "Fact Sheet - UFFI Repurchase Regulations." Boston, Massachusetts.

Massachusetts Office of Consumer Affairs, N. D. "Guide to the Sale of UFFI Homes." Brochure printed by The Provident Institution for Savings. Boston, Massachusetts.

Mika, Peggy, 1983. Insurers Fear Formaldehyde Exposure Claims." National Underwriter (Property/Casualty). 87(29):28, 40.

National Research Council (NRC), 1981. Formaldehyde and Other Aldehydes. Washington, D. C.: National Academy Press.

Oatway, Janet A., and Hans A. Klemm, 1981. Formaldehyde Regulatory Control Options Analysis. Draft Final Report. Contract No. 68-01-5960. Prepared for Office of Chemical Control, Environmental Protection Agency. Report No. GCA-TR-81-1-G. Bedford, Massachusetts: GCA Corporation.

Oregon Association of Realtors, n.d., a. "Notice to Sellers Regarding Urea-Formaldehyde Foam Insulation." 2 pp.

Oregon Association of Realtors, n.d., b. "Notice to Buyers Regarding Urea-Formaldehyde Foam Insulation." 2 pp.

Pickerell, J. A., L. C. Griffis, and C. H. Hobbs, 1982. Release of Formaldehyde from Various Consumer Products. Final Report. Prepared for Consumer Products Safety Commission. Report No. LMF-93, UC-48. Albuquerque, New Mexico: Lovelace Biomedical and Environmental Research Institute.

Reeves, Wilson A., Mary O. Day, K. Rinn McLellan, and Tyrone L. Vigo, 1981. "Formaldehyde Release in Formaldehyde- and Resin-Finished Fabrics". Textile Research Journal 51(7):481-485.

Repace, James L., 1982. "Indoor Air Pollution." Environment International 8:21-36.

Runzheimer Reports on Relocation, 1983. "Homes Discounted for 'Aggravation Factor.'" Trade newsletter. 2(6):5.

Savings and Loan News, 1983. "Insulation Exposes Lenders, Appraisers to Legal Challenge." 104(3):110-111.

Small, Bruce P., 1982. Chemical Susceptibility and Urea-Formaldehyde Foam Insulation. Cornwall, Ontario: Deco-Plan, Inc.

Smith, Charles, 1982. Urea Formaldehyde Foam Insulation - Final Economic Assessment of a Ban on Sales. Washington, D. C.: Consumer Product Safety Commission.

Snell Division, 1979. Preliminary Study of the Costs of Increased Regulation of Formaldehyde Exposure in the United States Workplace. Prepared for Formaldehyde Task Force of the Synthetic Organic Chemical Manufacturers Association. Florham Park, New Jersey: Booz, Allen, and Hamilton, Inc.

Telecom, 1984a. Telephone communication with M. E. Lough, Bennett Laboratories, Inc. regarding testing procedures for formaldehyde levels in structures, and the neutralization of UFFI. August 24, 1984.

Telecom, 1984b. Telephone communication with Connie Smercek, Save Us From Formaldehyde Environmental Repercussions (SUFFER) regarding formaldehyde standards and testing for formaldehyde concentrations. August 27, 1984.

Telecom, 1984c. Telephone communication with Dr. Leslie P. Williams, Oregon Department of Disease Monitoring and Control regarding levels of formaldehyde and associated symptoms experienced by residents in mobile homes. May 25, 1984.

Telecom, 1984d. Telephone communication with Lawrence P. Hanrahan, Wisconsin Department of Health regarding studies done on formaldehyde exposure in occupational and nonoccupational settings. May 25, 1984.

Thun, Michael J., Michael F. Lakat, and Ronald Altman, 1982. "Symptom Survey of Residents of Homes Insulated with Urea-Formaldehyde Foam." Environmental Research 29:320-334.

UFFI Centre, 1983. The UFFI (Urea-Formaldehyde Foam Insulation File. Information packet published by Consumer and Corporate Affairs Canada.

Versar, Inc., 1982. Exposure Assessment for Formaldehyde. Final Draft Report. Contract No. 68-01-6271. Prepared for Office of Toxic Substances, Environmental Protection Agency. Springfield, Virginia: Versar, Inc.

Wayland, R. Lee, Jr., Louis W. Smith, Julian H. Hoffman, 1981. "Low-Formaldehyde Finishing in Production." Textile Research Journal 51(4):302-309.

Wynn, Jack, 1983. "Prospects Brighten for Manufactured Homes." Barron's 63(1):49.

Youngquist, John, 1981. "Laminated Wood-Based Composites." In Mark, H. F., D. F. Othmer et al., ed. Kirk-Othmer Encyclopedia of Chemical Technology. v. 14. 3rd edition. New York: Wiley and Sons.

Appendix A

Sample Questionnaire

RESEARCH TRIANGLE INSTITUTE

Center for Economics Research

August 7, 1984

____
____
____
____
____

Dear ______________,

As promised in our recent telephone conversation, I am enclosing a questionnaire for a study of the effects of urea-formaldehyde foam insulation (UFFI) on housing values. We at the Research Triangle Institute (RTI) are conducting this survey as part of a study for the U.S. Environmental Protection Agency (EPA).

We are surveying realtors from several regions of the United States who have particular knowledge about the effects of UFFI in the housing market. We want you to provide detailed information about your experiences with detached single-family dwellings containing UFFI, as well as your opinions about such homes.

The questionnaire itself contains four sections; instructions for completing each are attached. The first section requests information on the characteristics of the UFFI-containing home(s) recently sold by you or someone else in your region. The second section asks for details about the sale of the home(s) described in the first section. The third section elicits your general impressions about the effects of UFFI on the housing market and the reasons for those effects. The fourth section requests your address and telephone number for future follow-up by RTI. Neither your name nor your firm's identity will be revealed to anyone outside RTI

Enclosed with your copy of the survey questionnaire and instructions you will find a stamped, addressed envelope for mailing your reply. Because our study must be completed very soon, we need your response as soon as possible. To incorporate your responses, we should receive them no later than Friday, August 24, 1984.

I will be in contact with you by telephone approximately 1 week from today. Please do not hesitate to call me at (919) 541-5847 if you have any questions or problems before then.

We appreciate your cooperation in this effort.

Sincerely,

Lu Lohr

Enclosures

Post Office Box 12194 Research Triangle Park, North Carolina 27709 Telephone: 919 541-6000

INSTRUCTIONS

SURVEY ON THE EFFECTS OF UREA-FORMALDEHYDE FOAM INSULATION (UFFI) ON HOUSING VALUES

Please read carefully and follow the instructions below.

GENERAL

1. Throughout the survey, the homes referred to are detached single-family dwellings containing urea-formaldehyde foam insulation (UFFI) at the time of sale. Confine your answers to these types of homes, except where otherwise indicated.

2. Type or legibly print all answers.

3. You are encouraged to call the contact person at Research Triangle Institute (RTI) as you feel necessary.

SECTIONS I AND II

1. Complete all items in Sections I and II. Both sections concern homes that you have actually sold or that you know have been sold. Complete columns for the two (or one) homes with UFFI that have most recently sold.

2. Note that the column headings--"Home 1" and "Home 2"--refer to the same dwellings in both Sections I and II.

SECTION III

1. Complete all relevant items in Section III. This section relates to the more general relationship between housing markets and UFFI, rather than any particular homes. The questions you answer will in some cases depend on the responses you give to previous questions. After certain responses, you are asked to proceed to another question by the statement "GO TO ___." The number following this phrase is the number of the next question you are to answer.

2. For Questions 1 through 3 and Questions 5 through 12 you are asked to compare homes with UFFI to homes with the same attributes but with another type of equally effective insulation.

3. Use Question 13 to describe your opinions concerning trends in the housing market due to UFFI or to describe other aspects of the housing market affected by UFFI but not discussed in this survey (e.g., availability of mortage loans, industry concerns with liability, effects on UFFI-containing homes that have been listed but not sold, etc.).

SECTION IV

1. Give full information in Section IV. Neither your name nor your firm's identity will be revealed to anyone outside RTI.

QUESTIONNAIRE

SURVEY ON THE EFFECTS OF UREA-FORMALDEHYDE FOAM INSULATION (UFFI) ON HOUSING VALUES

August 1984

Research Triangle Institute

P.O. Box 12194

Research Triangle Park, North Carolina 27709

I. CHARACTERISTICS OF HOUSES WITH UFFI

House Characteristic	Home 1	Home 2
1. Street address, city and state?		
2. Interior floor area (ft^2)?		
3. Number of baths (1, 1½, etc.)?		
4. Lot size (ft^2)?		
5. Garage (yes, no)?		
6. If yes, size (1-car, 2-car)?		
7. Age of home (years)?		
8. Style of home (ranch, Cape Cod, etc.)?		
9. Location of home in metropolitan/urban area (yes, no)?		
10. If yes, location within limits of central city (yes, no)?		
11. Special features which add to (+) or detract from (-) value (pool, view, neighborhood, etc.)?		
12. Date of UFFI installation if known (month, year)?		

II. SALE/COST DETAILS FOR HOUSES WITH UFFI

Sale/Cost Detail	Home 1	Home 2
1. Length of time on market (months)?		
2. Did presence of UFFI lengthen time on market (yes, no, unsure)?		
3. Date of sale (month, year)?		
4. List price with UFFI?		
5. Was UFFI a factor in determining list price (yes, no, unsure)?		
6. Sale price with UFFI?		
7. Was UFFI a factor in determining sale price (yes, no, unsure)?		
8. Was buyer aware of UFFI presence prior to sale (yes, no, unsure)?		
9. Was home tested for level of formaldehyde prior to sale (yes, no, unsure)?		
10. Were you (realtor) required by law to disclose presence of UFFI (yes, no, unsure)?		
11. Estimated sale price of same home with other type of insulation?		
12. Estimated cost to remove UFFI and replace it with alternative insulation?		

III. GENERAL EFFECTS OF UFFI ON THE HOUSING MARKET

1. In Section II, did the actual sales prices for the homes with UFFI differ from your estimated sales prices for the same homes with another type of insulation (check one)?

   _____ yes GO TO 2.

   _____ no GO TO 3.

2. To what factors do you attribute the difference between actual sales prices for homes with UFFI and your estimated sales prices for the same homes with another type of insulation (check all that apply)?

   _____ Actual offgassing problems due to improper installation of UFFI.

   _____ Actual offgassing problems even with proper installation of UFFI.

   _____ Stigma attached to UFFI homes due to negative publicity.

   _____ Buyer expects to incur cost of removing UFFI and replacing it with another type of insulation.

   _____ Other ______________________________

   ____

   ____

3. To what factors do you attribute the lack of difference between actual sales prices for homes with UFFI and your estimated sales prices for the same homes with another type of insulation (check all that apply)?

   _____ Testing prior to sales revealed no excess formaldehyde concentration.

   _____ Indifference of buyer to presence of UFFI.

   _____ Actual sale prices have already been adjusted to allow for the presence of UFFI.

   _____ List prices have already been adjusted to allow for the presence of UFFI.

   _____ Other ______________________________

   ____

   ____

4. Is it the practice of your firm to recommend testing for formaldehyde concentration levels in homes containing UFFI prior to their sale (check one)?

_____ yes

_____ no

_____ unsure

5. In general, is the presence of UFFI in homes a factor in determining their list prices (check one)?

_____ yes GO TO 6.

_____ no GO TO 8.

_____ unsure GO TO 6.

6. How does the presence of UFFI in homes affect their list prices (check one)?

_____ tends to increase it GO TO 7.

_____ tends to decrease it GO TO 7.

_____ unsure GO TO 8.

7. By what percent do the list prices of homes change due to the presence of UFFI (check one)?

_____% decrease

_____% increase

8. In general, is the presence of UFFI in homes a factor in determining their sale prices (check one)?

_____ yes GO TO 9.

_____ no GO TO 11.

_____ unsure GO TO 9.

9. How does the presence of UFFI in homes affect the sale prices (check one)?

_____ tends to increase it GO TO 10.

_____ tends to decrease it GO TO 10.

_____ unsure GO TO 11.

10. By what percent do the sale prices of homes change due to the presence of UFFI (check one)?

_____% decrease

_____% increase

11. In general, if placed up for sale, do homes containing UFFI remain on the market longer than homes having another type of insulation (check one)?

_____ yes GO TO 12.

_____ no GO TO 13.

_____ unsure GO TO 12.

12. How much longer do homes with UFFI remain on the market than homes with another type of insulation (check one)?

_____ 1 to 2 months

_____ 3 to 4 months

_____ 5 to 6 months

_____ more than 6 months

13. Do you have any other comments concerning UFFI and its effect on home sales or prices?

____

____

____

____

____

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IV. CONTACT INFORMATION

We would like your address and telephone number so we can contact you in the future about your response or about other relevant details, as necessary. We will not reveal either your name or your firm's identity to anyone outside the Research Triangle Institute (RTI).

Name ____

Firm ____

Business Address __________________________________

____

Business Telephone ________________________________

If you have any questions concerning this survey please contact:

Lu Lohr
Center for Economics Research
Research Triangle Institute
Post Office Box 12194
Research Triangle Park, North Carolina 27709
(919) 541-5847