returned to working condition after 30 to 60 minutes. The problem was a bad bearing that would sieze, but only when hot.

Graphs B and C were purposely drawn so that the flow rate at the end of eight hours approximated that at zero hours. That is what actually happens in many cases. The point, of course, is that flow checks at the beginning and the end of an eight-hour test period are no indication that a pump is field-ready. In some cases, the industrial hygienist will observe a pump break down. In other cases, the pump will appear to function but will deliver a volume of air that differs from that calculated by the hygienist. The error may be quite large unless newer pumps are used and the warnings they display are heeded.

The Pump Tester has been extremely useful in our laboratory for these routine performance tests. It has also been used for evaluating new pumps before a purchase. As mentioned previously, the Pump Tester could also be useful for more formal studies of pump performance. However, studies requiring high precision would require additional refinement of the system; the Pump Tester occasionally drifts up to 1.5 percent of full scale during an eight-hour test. The drift occurs in spite of the one-point calibration correction ("zero check") described in the Calibration and Operation section. The authors believe that the addition of a second calibration correction, based on a constant (nonzero) flow, would decrease drift to less than 0.5 percent.

Recommendations

To achieve reliable field operation of personal sampling pumps, every organization should have a maintenance program that includes a means of checking the work. The final check of overall pump performance should consist of an eight-hour test with continuous, or frequent, recording of flow rate. The check should be performed each time a pump is serviced, which will vary from six months to two years, depending on the type of pump and its usage. Small organizations can use a strip-chart recorder and electronic flow sensor to record flow rates during performance checks. When a large number of pumps must be maintained, a test system similar to the one described here may be justifiable. Without this kind of testing, critical data may be lost, or worse, erroneous data may be reported.

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#4741

Reassessment of Formaldehyde Exposures in Homes Insulated with Urea-Formaldehyde Foam Insulation

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The Connecticut Department of Health Services (DHS) responded to health complaints associated with urea-formaldehyde foam insulation (UFFI) between 1977 and 1983 with free air tests. As a result of investigation of health complaints in over 500 houses, UFFI was banned in Connecticut in 1981. However, a review of recent data obtained from private laboratories indicated that formaldehyde levels in the air of homes insulated with UFFI had dropped considerably since the time of installation and prompted this current study. This study was conducted to test the supposition that formaldehyde levels had dropped significantly since the late 1970s in homes that were insulated with UFFI during that time. Formaldehyde levels were measured in 30 homes, which had been tested by the DHS in the past, and were found to have had "high" levels. In addition, ten control non-UFFI homes were tested to establish background levels. The results of this study indicate that the formaldehyde levels in the "high" UFFI houses decrease from an average of 1.39 ppm at the time of original testing to 0.08 ppm in 1986. Average levels in the UFFI houses and the control houses were not statistically different. Despite these facts, a few "problem" houses were found which still had elevated formaldehyde levels. These results support the hypothesis that most UFFI houses no longer expose occupants to unhealthy or unusual levels of formaldehyde but that air testing of such houses may still be necessary to confirm the safety of any given house. Weintrub, L.N.; Toal, B.F.; Brown, D.R.: Reassessment of Formaldehyde Exposures in Homes Insulated with Urea-Formaldehyde Foam Insulation. Appl. Ind. Hyg. 4:147–152; 1989.

Introduction

Formaldehyde is a colorless gas with a pungent odor which, upon exposure, can cause symptoms such as eye, nose, and throat irritation, coughing, and dermatitis.[1] In addition, there is both animal and human evidence which indicates that formaldehyde may be carcinogenic.[2,3] An ubiquitous compound, it is a product of combustion and a component of many consumer products such as particle board, plywood, permanent press fabrics, carpeting, and cosmetics. Perhaps the most well known formaldehyde-containing product in homes is urea-formaldehyde foam insulation (UFFI). Particularly when UFFI is new, formaldehyde is released into the surrounding air, and some residents of homes containing UFFI have reported adverse health effects consistent with exposure to formaldehyde.[1]

Urea-formaldehyde foams were developed in Germany in 1933 and subsequently approved for home insulation in the United States in the early 1970s. Increased interest in energy conservation, particularly following the oil embargo of 1974, resulted in the widespread use of UFFI. It is estimated that UFFI was installed in 500,000 homes in the United States.[1] Its popularity was due to its efficiency in reducing heat loss, its relatively low cost, and its ease of installation, particularly as a retrofit insulation in existing homes.

UFFI was generated at the site of installation by mixing urea, formaldehyde, water, a catalyst, and a propellant such as compressed air. The foam was pumped under pressure into the wall cavities through small holes drilled in the exterior or interior walls and hardened within the walls. Following installation of the foam, formaldehyde off-gassed and entered the living areas of the homes. Factors affecting the release of formaldehyde included the quality and age of the ingredients, the proportion of ingredients in the mixture, the expertise of the installer, and the temperature at the time of installation.[4] The emanation of formaldehyde from UFFI occurred in two separate processes. Initially, free formaldehyde present in the resin escaped as a gas, but on a longer term, heat and moisture caused hydrolysis and decomposition that also resulted in the release of formaldehyde vapor.[4]

Because of concerns about the safety of the product, many state agencies and institutions, including the Connecticut Department of Health Services (DHS), responded to consumer complaints by measuring indoor air formaldehyde concentrations. In an early study conducted by the DHS, 69 UFFI homes in Connecticut were sampled using Draeger tubes after residents had officially complained.[5] Age of the insulation in this study ranged from 3 weeks to 1.5 years with a mean of 3 months, and formaldehyde concentrations ranged from less than 0.5 ppm to 8 ppm. Both this

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TABLE I. Review of Studies On Formaldehyde Concentration in UFFI Homes

Reference	Location	(N) UFFI Homes	Range UFFI Homes (ppm)	Mean UFFI Homes (ppm)	Median UFFI Homes (ppm)	(N) Control Homes	Range Controls (ppm)	Mean Controls (ppm)	Mean Age of Foam
5	Connecticut	69	0.50–8.0	—	—	—	—	—	3 mo
7	New Hampshire	81	0.01–0.17	—	—	—	—	—	—
8	Denver-Boulder, Colorado	10	0.010–0.112	0.039	—	3	0.010–0.025	0.019	4.3 yr
8	Southern Wisconsin	11	0.028–0.144	0.079	—	—	—	—	3.1 yr
9	Wisconsin	14	0.10–1.09	—	0.10	—	—	—	21.2 mo Median
11	Ottawa-Toronto, Canada	12	0.04–0.32	—	—	4	all 0.04	—	—
12	London, Canada	22	0.014–0.108	0.054	—	16	0.018–0.095	0.051	—
13	Canada	1298	—	0.054	—	383	—	0.036	—

study and a follow-up study by the DHS found an association between elevated formaldehyde levels and reported health effects.(6) Many other agencies also conducted formaldehyde surveys in UFFI homes (Table I).

The New Hampshire Air Resources Agency sampled 81 UFFI houses and found concentrations of formaldehyde ranged from 0.01 ppm to 0.17 ppm which were correlated with outdoor temperature and heating degree days.(7) In a Colorado study, formaldehyde levels in ten UFFI homes ranged from less than 0.010 to 0.112 ppm with a mean of 0.039 ppm, while the levels in the control homes ranged from less than 0.010 to 0.025 ppm with a mean of 0.019 ppm.(8) The same investigators reported the results of a study of 11 UFFI homes in southern Wisconsin where the formaldehyde concentrations varied from 0.028 to 0.144 ppm with a mean of 0.079 ppm.(8) No controls were sampled in the southern Wisconsin survey. Another survey in Wisconsin of 14 conventional homes insulated with UFFI found concentrations ranging from 0.10 to 1.09 ppm with a median of 0.10 ppm.(9) Median age of the foam was 21.2 months.

It is estimated that 60,000 houses in Canada were insulated with UFFI before it was banned there in 1980. A 1981 study of 50 homes in St. Johns, Newfoundland, revealed significantly higher formaldehyde levels in UFFI homes than non-UFFI homes.(10) A study in Ottawa and Toronto, Canada, of 12 UFFI houses found formaldehyde levels less than 0.04 ppm in 6 houses, 0.04 to 0.06 ppm in 4 houses, and up to 0.2 and 0.3 ppm in 2 houses.(11) As part of a study relating respiratory symptoms with exposure to formaldehyde, 22 UFFI homes and 16 non-UFFI homes in the London, Canada, area were sampled.(12) Formaldehyde concentrations in the UFFI homes ranged from 0.014 to 0.108 ppm with a mean of 0.054 ppm, while levels in control homes ranged from 0.018 to 0.095 ppm with a mean of 0.051 ppm. Consumer and Corporate Affairs Canada conducted an extensive survey of formaldehyde in 1298 UFFI homes across Canada.(13) The average level in the UFFI houses was 0.054 ppm, and in the control houses it was 0.036 ppm. Formaldehyde levels were found to correlate with the age of insulation and with the level of water vapor in the walls.

In response to reported health problems associated with residential formaldehyde exposures, several West European countries including Sweden, Denmark, the Netherlands, and West Germany have proposed or promulgated an indoor air quality standard of 0.10 ppm maximum concentration for formaldehyde. Although no residential standards have been established in the United States, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has recommended a standard of 0.10 ppm maximum concentration.(14)

A number of states throughout the United States responded to consumer complaints by promulgating regulations regarding the sale of UFFI. Connecticut banned the installation of UFFI in 1981 (Connecticut Public Act 81-250). Legislation passed in Massachusetts has resulted in the establishment of a trust fund to pay for air testing and remedial measures, including removal of UFFI if a level of 0.1 ppm formaldehyde is exceeded (Chapter 728 of Acts of 1985).

By the summer of 1986, UFFI in any Connecticut home was at least five years old, and there were indications from private laboratories that most of the free formaldehyde had dissipated and that the indoor air concentration of formaldehyde in UFFI homes was comparable to levels found in non-UFFI homes. However, concern over the presence of UFFI had remained high, particularly in the instance of house sales. This concern was partially responsible for the current study, which was undertaken in order to attain a better understanding of current formaldehyde concentrations in the indoor air of UFFI homes, both in relation to concentrations found during previous testing and in relation to concentrations found in non-UFFI homes.

Methods

Out of the 500 homes previously tested by DHS, the 30 homes that demonstrated the highest concentrations of formaldehyde were selected nonrandomly for resampling. Mobile homes and homes from which the UFFI had been removed were excluded from the study. Six of the 30 homes had been initially tested using the chromotropic acid method, while concentrations in the remaining 24 homes had been determined using the Draeger tube method. The climatic conditions present at the time of historical testing were not recorded in a regular fashion and were not standardized in any way. Testing was done in many different rooms, at all times of the day, and during different seasons. In the current study, houses were tested under worst case conditions whenever possible. Homeowners were instructed to keep the windows and doors closed for at least 24 hours prior to

testing if possible, and samples were collected in the afternoon or evening during the summer months when formaldehyde levels would be highest. In addition, ten control homes of DHS employees were tested under similar control conditions.

The samples were collected using an MSA Model S portable pump, calibrated to draw air at a rate of 1.0 L/min. The pumps were connected to three all-glass midget impingers in series, two of which contained 20 ml of a one percent sodium bisulfite solution. The impinger closest to the pump was empty in order to protect the sampling pump from potential water damage. Blanks were included with all samples to ensure an uncontaminated collecting medium. Air was collected for a one-hour time period, resulting in the sampling of 60 L of air per sample and a theoretical limit of detection of 0.01 ppm. Smoking was discouraged during the sampling period. Indoor and outdoor temperatures, as well as relative humidity inside each house, were measured during the sampling period using a sling psychrometer. Temperature and humidity conditions were not recorded when the historical samples were collected.

With the exception of two homes from which the air was sampled from only one room, air samples were collected from two separate rooms that were frequently used in each house and were known to have UFFI in exterior walls. All samples were analyzed by the Connecticut State Department of Health Services Laboratory, Industrial Hygiene Division, using the NIOSH Analytical Method Number P&CAM 125, Formaldehyde in Air.(15) The mean concentration of formaldehyde in each house was calculated by averaging the values of the two measurements.

Indoor formaldehyde levels vary significantly over the course of a day as well as from day to day, due primarily to variations in indoor temperature and humidity as well as ventilation.(16) In order to "standardize" the measured formaldehyde levels, each sample measurement was corrected for variations in temperature and humidity according to the method of Berge *et al*, as listed by Godish(17) using the following equation:

$$C_x = \frac{C}{[1 + A(H - H_o)]\, e^{-R(1/T - 1/T_o)}}$$

where:

C_x = corrected concentration (ppm)
C = test concentration (ppm)
e = natural log base
R = coefficient of temperature (9799)
T = test temperature (°K)
T_o = standardized temperature (°K)
A = coefficient of humidity (0.0175)
H = test relative humidity (%)
H_o = standardized relative humidity (%)

An indoor temperature of 24°C and 60 percent relative humidity were used as reference conditions since these values reflected "near worst case" environmental conditions present in the homes.

At the time of sampling, an adult resident of each UFFI house was interviewed qualitatively using a standard questionnaire about any lingering health effects among household members, lingering odors, and sources of formaldehyde in the home other than UFFI. Residents of the control homes were not questioned.

Mean formaldehyde levels in the UFFI homes and non-UFFI homes were compared using the two-tailed t-test and Wilcoxon's rank sum test. Correlation coefficients of formaldehyde levels with indoor temperature, outdoor temperature, relative humidity, and age of the insulation were also determined. Statistical analysis was done utilizing the Statistical Package for the Social Sciences (SPSS).

Results

The age of the insulation was unknown in two of the UFFI homes. The age of the insulation in the remaining 28 UFFI homes varied from 58 to 116 months, with a mean of 97 months and a median of 101.5 months. A frequency histogram displaying the distribution of ages is presented in Figure 1.

The mean (average of two tests per house) formaldehyde concentrations in the UFFI homes ranged from not detectable to 0.34 ppm (Figure 2), and in non-UFFI homes the mean levels ranged from not detected to 0.12 ppm. The distribution of formaldehyde levels in UFFI houses is shown in Figure 2. Table II lists the formaldehyde levels for all the UFFI homes along with original formaldehyde levels, age of the insulation, and the time between tests.

As shown in Table III, the mean concentration of formaldehyde in the air of UFFI homes decreased from 1.39 ppm at the time of the original sampling to 0.08 ppm during the summer of 1986, while the median decreased from 0.78 ppm to 0.06 ppm.

Measured formaldehyde levels in the ten non-UFFI homes revealed a mean of 0.04 ppm and a median of 0.02 ppm (Table III).

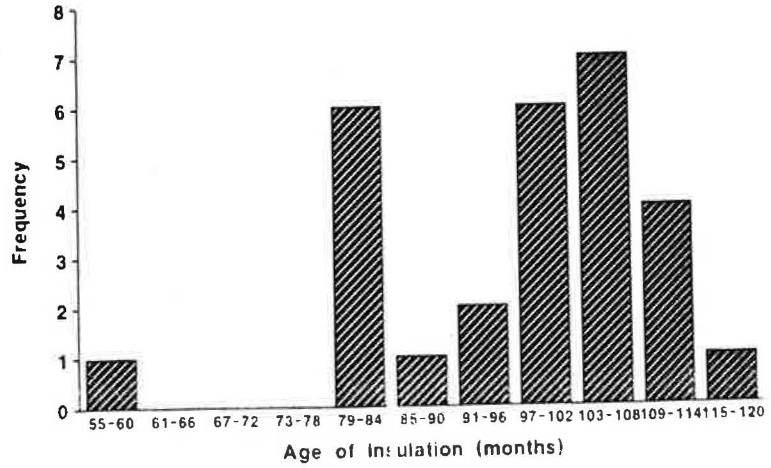

FIGURE 1. Distrib tion of UFFI ages.

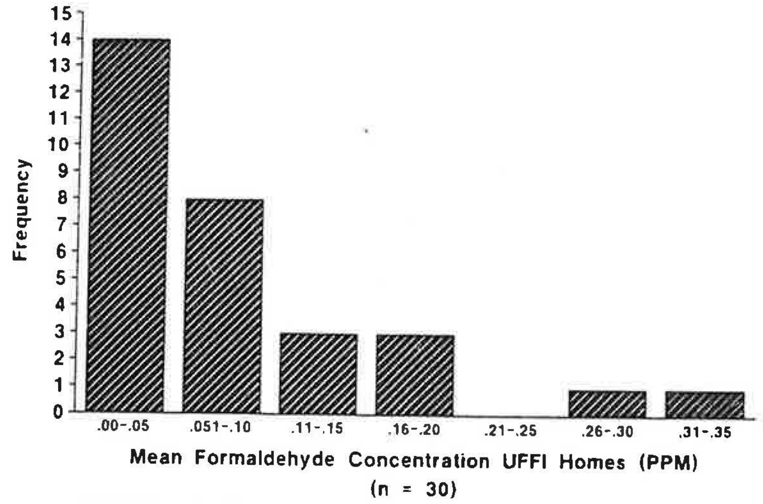

FIGURE 2. Distribution of formaldehyde concentrations in UFFI homes.

Because of a few high measurements, the median values are lower than the corresponding mean values. Standardizing the levels found in UFFI homes resulted in a decrease of the mean level to 0.06 ppm and a decrease of the median level to 0.045 ppm (Table III). Standardizing the concentrations in non-UFFI homes did not change the values of the mean or median.

TABLE II. Original and Retest Formaldehyde Levels with Age of UFFI and Elapsed Time Between Tests

House Number	Original Formaldehyde Level (ppm)	Elapsed Time Between Tests (mo)	Mean Formaldehyde Level of Retest (ppm)	Age of Insulation (mo)
1	0.80	86	0.05	100
2	0.10	48	0.02	58
3	0.17	62	0.01	102
4	0.13	51	0.06	84
5	0.21	49	0.02	83
6[A]	0.41	50	0.01	110
7	2.19	98	0.08	102
8	0.21	48	0.06	106
9	0.82	100	0.06	105
10[B]	0.50	102	0.18	104
11	7.00	84	0.08	86
12	2.00	73	ND	80
13	0.25	97	0.12	?
14	2.25	97	0.16	105
15	1.52	97	0.09	101
16	0.85	75	0.16	79
17	1.40	70	0.03	105
18	1.50	103	0.11	104
19	0.75	78	0.28	99
20[B]	7.00	99	0.34	101
21	3.50	81	0.12	83
22[A]	0.70	74	0.07	82
23	0.68	99	0.02	105
24	0.85	94	0.02	94
25	0.70	101	0.02	110
26	1.00	72	ND	?
27	0.68	105	ND	109
28	2.12	105	ND	109
29	0.70	93	0.03	94
30	0.60	102	0.09	116

ND = Not detectable—detection limit of 0.01 ppm.
[A]Homes from which only one sample was taken.
[B]Homes which had UFFI in both the walls and ceilings

Use of the two-tailed t-test and Wilcoxon's rank sum test revealed that the measured means of UFFI homes and non-UFFI homes are not significantly different ($t = 1.47$, $p > 0.05$) and that the standardized means of UFFI homes and non-UFFI homes are not significantly different ($t = 1.11$, $p > 0.05$). The proportion of standardized mean formaldehyde levels greater than 0.10 ppm was 23.3 percent for UFFI homes and 20 percent for non-UFFI homes, proportions that are not significantly different ($p > 0.05$). Analysis revealed formaldehyde levels were more highly correlated with indoor temperature ($r = 0.40$, $p < 0.05$) and outdoor temperature ($r = 0.44$, $p < 0.05$) than with relative humidity ($r = 0.19$, $p > 0.05$). Of the three parameters, outdoor temperature had the greatest predictive ability on formaldehyde levels ($R^2 = 0.19$).

An analysis was conducted to determine the effect of time on the decrease in formaldehyde levels. When all of the original formaldehyde levels are included in the analysis, the rate of decrease in formaldehyde levels appears to follow an exponential decay curve.

$$C_t = C_o e^{-kt}$$

where:

C_t = test concentration
C_o = original concentration
t = elapsed time
k = decay constant

From the data presented in Table II, the decay constant (k) was calculated for each of the 30 homes using elapsed time between tests along with original and retest formaldehyde levels. The average decay constant (k) for the 30 homes was 0.036, with a standard deviation of 0.017 and a median of 0.034.

Of the 105 persons living in the 30 UFFI homes at the time of sampling, only 5 individuals reported symptoms that they believed could be related to the presence of UFFI in their homes. These symptoms included coughing, heaviness in the chest, watery eyes, and hives, but none could be definitively associated with exposure to formaldehyde. Occupants of two UFFI homes were still able to detect an odor of formaldehyde, only on hot days in one home and in the attic and behind the eaves in the other home. In both of these homes, UFFI had been installed in

TABLE III. Formaldehyde Concentrations in UFFI and Control Homes

	Measured Concentrations (ppm)	Standardized Concentrations (ppm)
Current Concentrations		
Range	ND–0.34	ND–0.26
Mean	0.08	0.06
Median	0.06	0.045
Historic Concentrations		
Range	0.10–7.0	—
Mean	1.39	—
Median	0.78	—
Control Concentrations		
Range	ND–0.12	ND–0.14
Mean	0.04	0.04
Median	0.02	0.02

ND = Not detectable—limit of detection of 0.01 ppm.

the attic where installation was not recommended because of the potential for release of large amounts of formaldehyde.

Discussion

This study evaluated the concentration of formaldehyde in the indoor air of 30 Connecticut homes insulated with UFFI that had previously been tested by DHS and found to have high indoor air concentrations of formaldehyde. Homes were only included in the study if no mitigation of formaldehyde exposures, such as UFFI removal, had been conducted. Mean formaldehyde levels in UFFI houses dropped from a level of 1.39 ppm at the time of initial complaint (prior to 1983) to a level of 0.08 ppm in 1986. This fact graphically demonstrates the decrease in formaldehyde levels as the insulation ages.

A relationship between the age of the foam and indoor formaldehyde concentration was demonstrated with the concentration decreasing as the age of the foam increased. The relationship between UFFI age and formaldehyde levels can be thought of as an exponential decay process. The calculated decay constant (k) of 0.036 has a large amount of variation (SD = 0.017), indicating that a single decay equation is not appropriate to predict the formaldehyde decrease in all UFFI houses. However, this k value with its standard deviation does give a reasonable range of possible decay curves under which most UFFI houses probably fell. More frequent analysis in a number of study homes would be required to confirm such an exponential model.

Detectable indoor formaldehyde concentrations were also found in most of the ten control homes that were not insulated with UFFI. In spite of the fact that concentrations in UFFI homes were found to be slightly higher than those encountered in non-UFFI homes, the differences in concentrations were not statistically significant. It should be remembered that the ten control homes were those of DHS employees and were therefore not randomly selected. This may have lead to selection bias and limits the ability to infer about all non-UFFI homes.

The results of this study are consistent with findings reported by other investigators indicating that formaldehyde concentrations decrease as the UFFI ages. Other surveys in UFFI homes have also found formaldehyde levels generally less than 0.1 ppm (Table I). The largest of these studies (n = 1298) was done in Canada, where a mean formaldehyde level of 0.054 ppm was found.[13] The average formaldehyde concentration found in the current study of UFFI homes (0.08 ppm) is in the same general range as other research (Table I). This is significant since all testing in the current study was done under worst case conditions which was not true for other UFFI surveys. The results of this study support conclusions by other researchers that UFFI is not as significant a source of formaldehyde as it was previously.

Qualitative health effects information obtained from homeowners did not reveal a striking number of health complaints, although there were no control groups for comparison. This is in contrast to earlier studies conducted in Connecticut which did demonstrate increased rates of health complaints in homes soon after UFFI installation.[5,6]

The standardization of formaldehyde results did result in a slight drop in formaldehyde levels. The significance of this finding points out the possible effects of temperature or humidity on formaldehyde concentrations. However, this finding should be viewed cautiously since, as Godish points out, the statistical confidence of this standardization procedure is poor.[17]

This study suffers from the same limitations of many similar studies in that the homes investigated were selected in a nonrandom fashion based on consumer complaints or inquiry. However, the homes selected were those with the highest historic formaldehyde levels, and the levels still demonstrated a dramatic decrease. Another drawback of the study is the fact that most of the original measurements made at the time of complaint were determined by the use of Draeger tubes, a method whose results are suspect due to a limit of detection of 0.5 ppm and a margin of error of ± 25 percent. However, all the homes selected that were tested with Draeger tubes had formaldehyde levels greater than 0.5 ppm at the time of original testing, which would indicate a significant problem, at least qualitatively.

In this study, several UFFI homes with high current levels of formaldehyde were encountered, but several non-UFFI homes also demonstrated high concentrations. This may be a result of the high temperature and humidity conditions at the time of sampling but is understandable given the many potential formaldehyde sources in all homes such as carpeting, particleboard, furniture, and upholstery. In addition, two of the "high" houses had UFFI in the attics as well as the walls, a procedure which was not recommended even at the time of installation.

Conclusions and Recommendations

The results of this survey indicate that with only a few exceptions the concentrations of formaldehyde in the indoor air of homes insulated with UFFI foam and sampled by DHS have decreased over time and are now comparable to homes that are not insulated with UFFI. Very few, if any, occupants are currently reporting health effects attributable to UFFI. However, the possibility exists that a few homes with UFFI in Connecticut still have formaldehyde levels high enough to warrant concern. This is particularly true for homes in which the UFFI was improperly installed, i.e., in attics or ceilings. Professionals who are contacted by concerned homeowners for air testing in UFFI homes should be aware that formaldehyde levels in those homes will usually be below 0.1 ppm. Sampling procedures should be selected to allow for a limit of detection of at least 0.05 ppm or lower. In general, indicator tubes will not have the sensitivity needed. In addition, homeowners should be educated to the fact that as residents of UFFI houses they are not necessarily being exposed to dangerous levels of formaldehyde especially in relation to other formaldehyde exposures.

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The Progression of Industrial Hygiene

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Industrial hygiene in the United States began with the work of Alice Hamilton during the first and second decades of the 20th century. After educational efforts initiated at Harvard University in the late 1920s, there was growth stemming from the Social Security Act in the 1930s, with selected states providing services. The American Conference of Governmental Industrial Hygienists was formed in 1938 and the American Industrial Hygiene Association in 1939. The Second World War and the immediate postwar period provided some growth of industrial hygiene in the private sector. Increased federal legislation addressing the environment called for research, training, and, ultimately, regulation in the 1960s; this set the stage for the landmark Occupational Safety and Health Act (OSHAct) of 1970. In this article, pre-OSHAct and post-OSHAct industrial hygiene regulation and practice are characterized by six distinct periods of time. Each period is described and characteristics of, or implications for, professional practice are noted. The periods are

1950–1960 Benign Neglect of Occupational Safety and Health
1960–1970 The Environmental Counterpart and Stimulus
1970–1975 The Occupational Safety and Health Administration Startup: Early Childhood Patterns
1975–1980 Adolescence
1980–1988 Deregulation and "Downscaling"
1989–1995 Adulthood

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Introduction

It is an honor and a privilege to be invited to reflect on the past, current, and future status of industrial hygiene. We are living in an exciting, challenging time with many existing opportunities for progress, but there are also risks of retrogression. It is incumbent upon us to reflect on where we have been and where we may be going.

The Early Years

Industrial hygiene had its roots in the work of Alice Hamilton during the second and third decades of this century.[1] In her autobiography, she described her efforts at the local and then the national level to improve extremely hazardous working conditions. In the United States, the efforts to promote this field were initiated through education, primarily at the Harvard School of Public Health during the late 1920s when Cecil Drinker, a physiologist, called upon his brother, Philip Drinker, to join him in investigations of human breathing, with particular emphasis on apparatus which would assist victims of tuberculosis. The investigations resulted in the "iron lung," which helped countless numbers of respiratory impaired individuals. Philip Drinker, a chemical engineer, also investigated the environment and those factors which appeared to adversely affect health. In those years, factory lighting was inadequate, as was ventilation. Reports of factory production increases with improved lighting stimulated progress.[2] Constantine Yaglou joined Philip Drinker, and major findings appeared defining the adequacy of ventilation for occupied spaces.[3]

Studies of the properties of dust were also started at Harvard.[3] In the 1930s, a small group of individuals interested in particle properties formed the Konimeter Club in Boston and met informally on a monthly basis. The work of Ted Hatch appeared in 1933, providing the famous Hatch-Choate equations that we draw heavily upon today. Dallavalle performed his studies of air flow in the vicinity of suction openings, laying the groundwork for our ventilation designs. Leslie Silverman continued these studies with publication of his Ph.D. thesis in 1939.

Occupational health as a field was growing under the influence of the Social Security Act which provided funds to the states to improve working conditions.[4] The individuals responsible for delivering these services founded the American Conference of Governmental Industrial Hygienists (ACGIH) in 1938 to share and disseminate technical information and to standardize methods for evaluating working conditions. The American Industrial Hygiene Association (AIHA) was formed a year later as the states pressed their programs on large companies, and the latter increasingly employed industrial hygienists.

World War II and the Immediate Postwar Years

The Second World War provided great impetus to industrial hygiene. Investigations of heat stress, respirator utilization, and dust measurement occurred during this period.[3] Harvard University initiated a short course for the U.S. Navy and later for the U.S. Army to train individuals who could evaluate working conditions

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