TABLE 1. Material Test Results
(Inside air temperature 23°C, relative humidity 35%)

Location	HCOH Conc (ppm)
Box A, top of living room carpet	0.45
Box B, U/S of kitchen cupboard shelf (unfinished)	0.75
Box C, back of wall panel above furnace	0.85
Box D, inside surface of wall panel with 300 mm × 5 mm crack	2.0
Box E, inside surface of wall panel	1.7
Box F, top of bedroom carpet	0.35
Inside of kitchen cupboards over refrigerator	1.15
Inside of water heater closet	0.65
Inside of interior wall cavity (bedroom)	3.25
Inside of exterior wall cavity	0.5

HEALTH STATUS OF RESIDENTS IN HOMES INSULATED WITH UREA FORMALDEHYDE FOAM

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The purpose of this study was to compare the health status of the occupants of 450 UFFI homes with that of 225 control homes. Each house was monitored for both formaldehyde and carbon dioxide, while the occupants were assessed using a health questionnaire and tests of pulmonary function, nasal airway resistance, sense of smell, nasal inflammatory cell and epithelial cytology, as well as contact sensitivity to formaldehyde and urea formaldehyde resin. The formaldehyde levels of the UFFI houses were found to be fractionally higher than those of the controls, while the carbon dioxide levels were similar across all groups. The UFFI house occupants showed an excess of numerous symptoms relative to the controls, and a small increase in the degree of squamous metaplasia of their nasal lining cells. Also, level of formaldehyde exposure showed a direct relationship with a number of symptoms present in excess among the UFFI house occupants. These results represent a preliminary phase in the analysis of these data, and tentatively indicate that living in a UFFI house is associated with subjective and to a lesser extent objective indicators of adverse health effects.

Title: HEALTH STATUS OF RESIDENTS IN HOMES INSULATED WITH UREA FORMALDEHYDE FOAM

Introduction

There is considerable concern that the occupants of houses insulated with urea formaldehyde foam (UFFI houses), are at risk to develop adverse effects on their health (reviewed by L'Abbé and Hoey)[1]. Nevertheless, this concern has not previously been validated by studies utilizing a scientific experimental design.

The purpose of the following study is to compare the health status of the occupants of 450 UFFI homes with those of 225 control homes. Each household is being examined on two occasions separated by an interval of 12 months, during which the foam will have been removed from half of the UFFI homes. The present report deals with a preliminary phase of analysis of the first examination.

Experimental Methods

Design of Study. The houses are assembled in sets of 3, consisting of one control, a second containing UFFI which is to be removed, and a third insulated with urea formaldehyde foam which is to remain in situ during the study period. The households in each set of 3 are examined over the same 4 to 6 week period, and are located within an approximate radius of 1 mile. The houses are balanced as well as possible across the 3 groups on the basis of age and the smoking habits of the occupants. All of the houses are structurally detached and are situated within a 60 mile radius of central Toronto.

Approximately one-half of the sets of houses also contained a fourth house where the occupants were planning to seal the wall cavities containing UFFI and perhaps to install an air to air heat exchanger. However, this group was deleted from the current report in order to maximize the number of full sets analysed.

Definition of Population. The UFFI houses are identified through the assistance of The UFFI Information and Co-ordination Centre, in which approximately 50% of all Canadian UFFI households were registered at the time this study was initiated in 1983. All of the UFFI houses were stated by their owners to contain UFFI; 98% were registered with the UFFI Information and Co-ordination Centre as containing UFFI; and the UFFI status was validated by our group in 65% of houses through inspection of the invoice of the contractor who had installed the UFFI. Control homes are enlisted in the same areas as UFFI homes by the use of address directories. The willingness of households to participate is ascertained by telephone, and at the same time the information is collected which enables the households to be grouped, matched and balanced. Information obtained from the UFFI Centre files indicated that the households which volunteered to participate in this study did not differ from the remainder of the registered UFFI homes, on the basis of either indoor formaldehyde levels, or of having lodged a health complaint with the Centre. Similarly, a brief questionnaire administered to all telephoned households refusing to participate in this study, demonstrated relative differences in the prevalence of health complaints between UFFI and control households which were comparable to those of the participating households.

Data Collection. The assessment of each household consists of two components, the first focussing on the house and the second on the occupants. The examination of the house includes a questionnaire dealing with construction details and sources of indoor air pollution, as well as the monitoring of formaldehyde and carbon dioxide levels. The examination of the occupants

includes a health questionnaire; spirometric assessment of pulmonary function; measurement of nasal airway resistance; examination of nasal inflammatory cell and epithelial cytology; determination of sense of smell threshold for pyridine; and patch tests for cutaneous allergy to formaldehyde. All data are collected on subjects aged 16 and over, while the patch tests are excluded for those under the age of 16. Only the questionnaire is completed for those under the age of 10.

Formaldehyde is monitored using an enclosed instrument consisting of a pump and two midget impinger bottles in series. Each impinger bottle contains 10 ml of 0.1% sodium bisulphite. The pump is controlled by a timer switch and the flow rate is adjusted to 500 ml per min. The flow rate is checked with a Kurz flow meter before and after each use. Formaldehyde is assayed by a modification of the NIOSH chromatropic acid method[2]. Each house is monitored for formaldehyde during two successive days, one of which coincides with the day on which the household is examined. This procedure is performed under normal operating conditions of the household. The sites monitored in each house are a central location such as a hallway, all bedrooms which are in use and the backyard. The backyard monitor is protected by an insulated container which contains a port through which the outside air is sampled. Each sampler runs for 5 hours, from approximately 3:00 to 8:00 P.M. in the central location and backyard, and from midnight to 5:00 A.M. in the bedrooms. Where possible, one member of the household is provided with a monitor to run on one day at their place of work.

CO_2 is monitored using Gastec detector tubes (300-5000 ppm), on the same occasions as formaldehyde, both in a central interior location and outside of each house. This measurement was introduced after the study was initiated and is available for about one-third of the houses, all obtained between the months of October 1983 through March 1984.

Pulmonary function is measured with an 8 liter rolling seal spirometer, equipped with a potentiometer, a kymograph and a microprocessor (Collins Eagle or Apex). The subjects perform the test wearing nose clips and sitting in a wooden chair. The measurements obtained are the FVC, FEV_1, peak expiratory flow rate (PEFR), flow rate between 25 and 75% of vital capacity (FEF_{25-75}), and flow rates at each of 25% and 50% of vital capacity (FEF_{75} and FEF_{50}).

Transnasal pressure and flow is measured using an instrument which includes a pneumotach connected to a scuba mask worn by the subject, as well as a pressure transducer linked to an oropharyngeal tube[3]. Nasal airway resistance is derived from the pressure and flow measurement.

The sense of smell is assessed using serial dilutions of pyridine in light mineral oil, as modified by Olfacto Labs (El Cerrito, California) from the method of Sherman and co-workers[4]. Pairs of spray bottles containing control and test solution which are unidentifiable to the subject, are used for each of 3 increasing concentrations of pyridine. The lowest concentration of pyridine which is correctly distinguished from control on 3 successive attempts is recorded as the threshold for a given subject.

Nasal epithelial cytology is examined in a Cytopathology Laboratory, on a swab obtained from a site 3 cm within the right nostril of each subject. The cells are fixed in 95% ethanol and prepared for examination with Papanicolaou stain. The number of polymorphonuclear and species of epithelial cells are individually estimated to the nearest hundred. This examination is performed without knowledge of whether the subject is from a UFFI or control home.

Patch tests are done using 2% formaldehyde in water, 0.05% urea formaldehyde resin in petrolatum, and as controls, petrolatum and 12% wood tars in petrolatum. The results are read at 48 hr.

Results

These data are based on the initial examination of 2074 occupants of 675 houses. The houses consist of 225 sets of 3, each set containing a control, a UFFI no action and a UFFI removal house, which were located in a similar area and were examined in the same period of the year.

Characteristics of Houses. The UFFI houses are 20-25% older than those in the control group (Table I). The houses do not otherwise differ significantly across the 3 groups in the number of occupants per house, the time of year in which they were examined, the occurrence of smoking, and the indoor CO_2 levels. The interval since UFFI was installed are comparable in the 2 UFFI groups. The indoor formaldehyde levels also are similar in the UFFI groups, and are significantly higher than in the control houses. All groups are comparable in architectural style, construction materials, and the presence of non-UFFI insulation, various forms of weatherproofing, heating sources and air conditioning. The houses in all groups are further comparable in estimated socio-economic appearance.

General and Medical Need Characteristics of Occupants. The subjects in the UFFI no action group show small but significant increases in both age and caucasian extraction than the other 2 groups (Table II). All 3 groups are similar in gender distribution and smoking experience. Both UFFI groups have a significantly higher prevalence of current medication use than the controls, while the UFFI removal group significantly exceeds the others in days of time loss. All groups are similar in doctor visits and hospital admissions during the previous year, as well as ever having undergone surgery. The excess of medication use in the UFFI subjects was lost when adjustment was made for possible confounding variables (see below).

Surface Irritation and Diverse Symptom Variables. Irritation of the throat, eyes and skin as well as a series of diverse symptoms are significantly increased among the UFFI removal group relative to both the UFFI no action and the control group (Table III). The prevalence of these symptoms among the UFFI no action group is either similar or only modestly increased relative to the controls. There is no significant difference between the groups in diarrhea or menstrual trouble. The latter variable is based only on females over the age of 15.

Three of these symptoms were inserted in the questionnaire to serve as "placebo" variables: trouble hearing, constipation and arthritis. These were selected since they are not listed in various reports of symptoms described by occupants of UFFI-insulated homes or mobile homes with high formaldehyde levels due to particle board, not UFFI. Trouble hearing and arthritis are reported in significantly higher prevalence in all UFFI subjects than in controls, while constipation is significantly more prevalent in the UFFI removal group than in the others. The excess of arthritis in the UFFI subjects was lost when adjustment was made for possible confounding variables (see below).

Nasal Variables. The nasal symptom variables are significantly increased in the UFFI removal group relative to the others (Table IV). Only nasal discharge is significantly elevated in the UFFI no action group compared with the controls. The nasal airway resistance and sense of smell threshold for pyridine are similar in all groups. The number of polymorphs obtained from the nasal swab is significantly diminished in the UFFI no action group relative to both other groups, while squamous metaplasia is observed significantly more often

in the UFFI removal group. The difference in polymorphs was lost when adjustment was made for possible confounding variables (see below).

Allergy, Respiratory Infection and Pulmonary Variables. The groups do not differ in their prevalence of hay fever, allergies, positive patch tests or ever having had pneumonia (Table V). However, the number of colds experienced in the past year is significantly increased in the UFFI removal group. There is a small but significant increase in the prevalence of cough in the UFFI removal group relative to the controls, and in the prevalence of sputum in the UFFI no action group relative to the controls. The pulmonary function results do not differ across the groups, either with or without adjustment for age, height and other possible confounding variables (see below). The prevalence of wheeze, and cough and sputum present 3 months per year became significantly different between the control and UFFI subjects following adjustment for possible confounders.

Additional Data Analysis. The relationship was examined between the onset of symptoms and the installation of UFFI. With few exceptions, any excess of symptoms in the UFFI groups relative to the controls is explained by an equivalent increase in onset during or following the year of UFFI installation. This suggested that the onset of excess symptoms within the UFFI subjects did not precede their exposure to UFFI.

Multiple regression analysis was performed with each health indicator as a dependent variable, and with the independent variables being group, race, age, gender, height, active or passive smoking status, number of hours spent in the house per week and household formaldehyde level. The purpose was to adjust for the effects of possible confounding variables and to determine whether exposure-response relationships were present. This analysis resulted in a loss of the relationship between UFFI group and medication use, arthritis and nasal swab polymorphs, that were initially demonstrated to be significant by the chi square statistic or analysis of variance (Tables II, III and IV). Wheeze ($p = 0.05$) and diarrhea ($p = 0.02$) were found to demonstrate a significant direct relationship with UFFI group membership in the multiple regression analysis, but had not done so in the initial chi square tests and analysis of variance (Tables III, IV and V). A significant direct relationship also was defined between mean indoor formaldehyde level and dizziness ($p = 0.005$), diarrhea ($p = 0.05$), eye irritation ($p = 0.002$), nosebleed ($p = 0.03$), cough ($p = 0.009$) and sputum ($p = 0.0002$). There were no significant relationships between number of hours spent in the house per week and any indicators of abnormal health.

Conclusions

The UFFI houses are significantly older than the controls, despite our best efforts to balance the houses across sets (Table I). This finding likely indicates that the UFFI houses tend to be the older structures within a given residential area. This could be due both to the older houses being more in need of retrofit insulation, and to the insulation subsidy program under which most UFFI was installed being phased in with the oldest houses qualifying earliest.

The occupants of the UFFI no action houses are significantly older than those of the UFFI removal and control groups (Table II). We interpret this as indicating that older people were less interested or less able to afford the expense of having their UFFI removed. Age of the subjects thus becomes a possible confounding variable in unadjusted statistical analyses. Several relationships of health indicator variables with the three household groups either lost (medication use, arthritis and polymorphs), or gained (wheeze and diarrhea)

statistical significance when age and other possible confounders are adjusted across the groups by multiple regression analysis.

The groups also differ slightly in the per cent who were caucasian (Table II). However, the findings are not altered if racial origin is included or excluded from the independent variables utilized in the multiple regression analysis.

Both UFFI groups tend to have an excess of abnormal health indicators relative to the controls (Tables II - V). However, the excess is almost always greatest in the UFFI removal group. This is perhaps to be expected, since people who recognized the occurrence of UFFI-related adverse health effects would be the most likely to be planning to have their UFFI removed.

Our data provide both subjective and objective evidence that UFFI exposure is associated with an excess of indicators of abnormal health. The questionnaire symptom variables are largely subjective and carry the least credibility, since these may be viewed as being susceptible to suggestion from the considerable media attention which the UFFI issue has received. The same may be said for the fact that the excess of UFFI-related symptoms tended to follow the installation of UFFI. This can be bolstered by the fact that the excess of symptoms include the "placebo" category (Table III). However, the complaints of cough, sputum and nosebleeds (Tables IV and V) are unlikely to be appreciably influenced by this consideration, since these are relatively objective symptoms. Also, nasal symptoms are among the most prominent complaints reported by the UFFI subjects (Table IV), and objective validation of these is provided by a significant increase in squamous metaplasia of the nasal epithelial cells, which is considered to represent a response of the nasal epithelium to irritation.

Objective support for the validity of the excess of symptoms is further provided by the fact that a number of complaints show a direct relationship with the indoor formaldehyde level. It might be argued that these relationships are fortuitous, since the indoor formaldehyde levels tend to be higher in UFFI houses. A fortuitous relationship could be further supported by the fact that the relationship of excess symptoms with the UFFI groups are generally stronger than the relationship of the same symptoms with formaldehyde levels. However, the relationship between symptoms and formaldehyde are stronger than between symptoms and UFFI groups in the case of both sputum, and cough and sputum present 3 months per year. These exposure-response relationships imply that formaldehyde may be the causative material, but they do not exclude the possibility of some other material being responsible, which parallels the presence of formaldehyde.

Thus the present results indicate that living in a UFFI house is associated with both subjective and objective indicators of adverse health effects. However, these results should be considered tentative, since they represent a preliminary phase of our analysis and may be modified by future refinements. Also, it should be stressed that the major differences between occupants of UFFI and control houses are in subjective complaints, while the objective differences are small and observed only when relatively large groups are examined.

References

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TABLE I. CHARACTERISTICS OF HOUSES

	control	UFFI no action	UFFI removal	chi sq or anova p[a]	sources of p ≤ 0.017[b] 1 vs 2	1 vs 3	2 vs 3
no. of houses	225	225	225				
no. occupants/house	3.2	3.2	3.1				
$\bar{x}$ month of visit	7	7	7				
smoke: occupants	44%	39%	39%				
visitors	27%	17%	21%				
duration of UFFI (yr)	0	4.8	4.7	0.0001	✓	✓	
age of house (yr)	32	42	40	0.0001	✓	✓	
carbon dioxide: indoor	733	757	714				
(ppm) outdoor	344	358	340				
formaldehyde: indoor	0.035	0.045	0.044	0.0001	✓	✓	
(ppm) outdoor	0.005	0.005	0.005				

[a] a blank indicates a p value greater than 0.05.

[b] each individual analysis is corrected for the multiple comparison problem by dividing the actual p value by 3.

TABLE II. GENERAL AND MEDICAL NEED CHARACTERISTICS OF OCCUPANTS

	UFFI control	UFFI no action	UFFI removal	chi sq or anova p[a]	sources of p ≤ 0.017[b] 1 vs 2	1 vs 3	2 vs 3
no. of occupants	695	670	709				
age (yr)	35	41	37	0.0001	✓		✓
male	49%	49%	51%				
caucasian	97%	99%	95%	0.001	✓		✓
smokers: non	57%	56%	59%				
ex cig	19%	21%	21%				
ex other	4%	4%	3%				
still cig	18%	16%	16%				
still other	3%	2%	2%				
pack years	23	26	25				
medication now	25%	33%	31%	0.003[c]	✓	✓	
days of time loss 1 yr	4	5	8	0.006		✓	✓
doctor visits 1 yr	4	4	4				
hospital admission 1 yr	11%	11%	11%				
operations ever	62%	65%	62%				

[a] a blank indicates a p value greater than 0.05.

[b] each individual analysis is corrected for the multiple comparison problem by dividing the actual p value by 3.

[c] this p value became greater than 0.05 when the analysis was adjusted for possible confounders using multiple regression analysis (see text).

TABLE III. SURFACE IRRITATION AND DIVERSE SYMPTOM VARIABLES

	control	UFFI no action	UFFI removal	chi square p[a]	sources of p ≤ 0.017[b] 1 vs 2	1 vs 3	2 vs 3
throat discomfort	5%	9%	16%	0.0001	✓	✓	✓
eye irritation	12%	18%	25%	0.0001	✓	✓	✓
skin rash	13%	12%	19%	0.0002		✓	✓
headache	18%	17%	25%	0.0002		✓	✓
dizziness	4%	7%	10%	0.0005		✓	
tire easily	16%	21%	28%	0.0001		✓	✓
trouble hearing	10%	18%	18%	0.0001	✓	✓	
thirst	5%	7%	13%	0.0001		✓	✓
nausea	2%	3%	4%	0.04		✓	
diarrhea	3%	4%	5%	c			
constipation	3%	4%	8%	0.0003		✓	✓
menstrual trouble	7%	5%	11%				
arthritis	14%	21%	19%	0.0008[d]	✓	✓	

[a] a blank indicates a p value greater than 0.05.

[b] each individual analysis is corrected for the multiple comparison problem by dividing the actual p value by 3.

[c] this p value became less than 0.05 when the analysis was adjusted for possible confounders using multiple regression analysis (see text).

[d] this p value became greater than 0.05 when the analysis was adjusted for possible confounders using multiple regression analysis (see text).

TABLE IV. NASAL VARIABLES

	control	UFFI no action	UFFI removal	chi sq or anova p[a]	sources of p ≤ 0.017[b] 1 vs 2	1 vs 3	2 vs 3
runny nose	10%	16%	22%	0.0001	✓	✓	✓
stuffy nose	20%	20%	32%	0.0001		✓	✓
nose bleed	6%	4%	12%	0.0001		✓	✓
nasal resist (cm H_2O/l/sec)	2.8	2.9	3.0				
pyridine smell threshold:							
0.00005%	6%	8%	7%				
0.0008%	42%	37%	38%				
0.012%	48%	50%	50%				
higher	4%	5%	4%				
cytology:[c]							
polymorphs	187	147	173	0.0002[d]	✓		
squamous	165	150	167				
anuclear sq.	81	79	84				
sq. metaplasia	16	18	24	0.02			
atypical sq.	4	2	4				
ciliated columnar	83	88	90				
non-ciliated col.	109	118	123				
irregular col.	1	2	2				

[a] a blank indicates a p value greater than 0.05.

[b] each individual analysis is corrected for the multiple comparison problem by dividing the actual p value by 3.

[c] each cell type is expressed in terms of estimated number of cells per sample.

[d] this p value became greater than 0.05 when the analysis was adjusted for possible confounders using multiple regression analysis (see text).

TABLE V. ALLERGY, RESPIRATORY INFECTION AND PULMONARY VARIABLES

		control	UFFI no action	UFFI removal	chi sq or anova p[a]	sources of p ≤ 0.017[b] 1 vs 2	1 vs 3	2 vs 3
hay fever		12%	11%	11%				
allergy		31%	31%	34%				
patch tests:	petrolatum	0	0	0				
	wood tar	0	0	1%				
	formaldehyde	0	1%	0				
	U.F. resin	0	0	0				
colds 1 yr		1.8	1.8	2.2	0.005		✓	✓
pneumonia ever		18%	20%	19%				
cough		11%	14%	18%	0.002		✓	
sputum		8%	12%	11%	0.03	✓		
wheeze or asthma		8%	9%	11%	[c]			
FVC (1)		4.15	4.02	4.10				
FEV_1 (1/sec)		3.43	3.32	3.38				
FEF_{50} (1/sec)		4.58	4.49	4.57				
FEF_{75} (1/sec)		1.80	1.77	1.78				

[a] a blank indicates a p value greater than 0.05.

[b] each individual analysis is corrected for the multiple comparison problem by dividing the actual p value by 3.

[c] this p value became less than 0.05 when the analysis was adjusted for possible confounders using multiple regression analysis (see text).

"UFFI - IT'S ROLE AS A MODEL IN THE STUDY OF INDOOR AIR QUALITY PROBLEMS"

BY

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Concerns relative to indoor air quality have recently focussed on the health effects of urea formaldehyde foam insulation (UFFI). Available information at the time of the expert committee deliberations in 1980-1981 on human exposure to formaldehyde, thought to be the main offender in UFFI-related symptoms, was limited by the lack of controlled studies on human exposure. The weight of evidence was sufficient with respect to short and long term effects of UFFI in living environments to recommend restricting its use in Canada.

Important remaining questions on human exposure to UFFI led to a series of controlled tests using a specially devised environmental chamber which could control exposure over time to pre-determined concentrations of formaldehyde, UFFI off-gases and dust particles on airway function on subjects complaining of asthmatic symptoms relative to UFFI. This study used 27 subjects (23 asthmatics with previous long-term exposure to UFFI and 4 non-exposed asthmatics) who were exposed to a placebo condition, formaldehyde gas (0.54 ppm), dust particles (0.5 particles/ml), and off-gas emitted from wet, moldy UFFI in the chamber. Eight of the 27 subjects (including two placebo responders) showed a 15% reduction in FEV_1 to one or other of the products and an overall 43.3% increase in eosinophilia was found after the exposures. In the subjects previously exposed to UFFI, small but statistically significant reductions in FEV_1, PEFR and FEV_1/FVC were seen 24 hrs after exposure to the dust.

Results indicate that UFFI-released products affect airway responsiveness in a small number of persons including those who have had previous exposure to UFFI as well as those who have not but have airway irritability. Eosinophilia in the group after the exposures raises the possibility that hypersensitivity to one or more of the products may be a factor in the development of UFFI-related asthma.

The results suggest that short-term exposure to materials believed to cause health effects under controlled conditions might be a valid method of testing for the detrimental effects of these and other substances on indoor air quality.