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Seasonal Variations in Formaldehyde Concentrations in Homes Insulated with Urea-Formaldehyde Foam

by J.L. Sullivan, C.J. Shirtliffe and J.M. Svec

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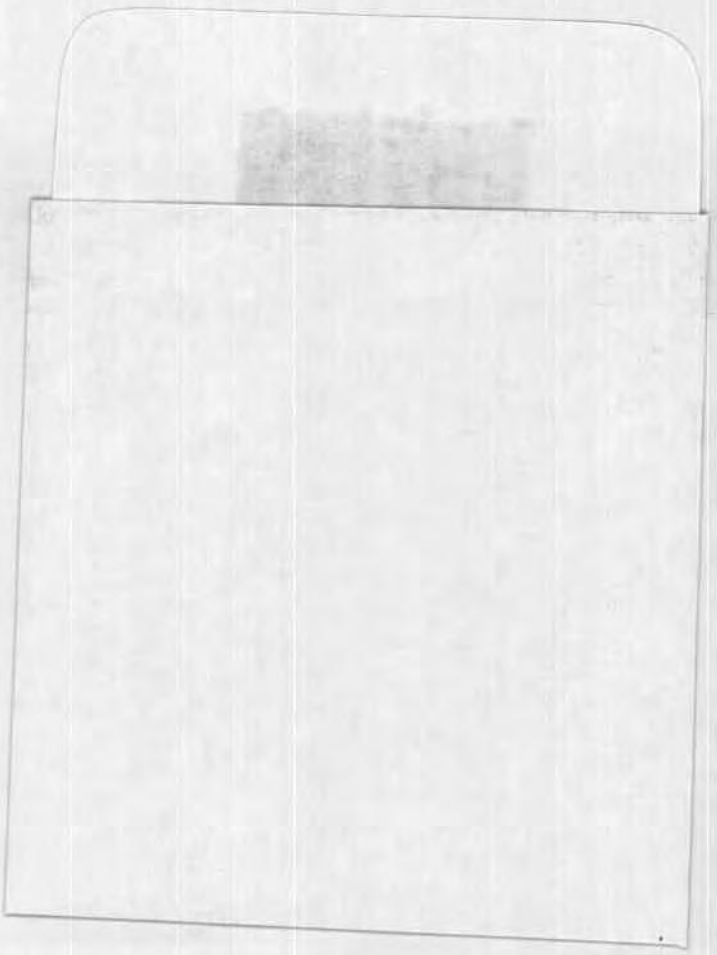
ABSTRACT

Recent study indicates that outdoor temperature influences room air and wall cavity formaldehyde concentrations in most, but not all, homes containing formaldehyde insulation.

RÉSUMÉ

Une étude récente a révélé que la température extérieure influe sur l'air intérieur et sur les concentrations de formaldéhyde dans les cavités des murs de la plupart mais non pas de toutes les maisons isolées à la MIUF.



SEASONAL VARIATIONS IN FORMALDEHYDE CONCENTRATIONS IN HOMES INSULATED WITH UREA-FORMALDEHYDE FOAM

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This study was conducted for the purpose of investigating a suspected relationship between residential air-borne formaldehyde and one or more seasonal factors. For that purpose, indoor air and wall cavity formaldehyde analyses were performed for a one year period on 26 London, Ontario, homes with urea-formaldehyde foam insulation (UFFI) and 6 control homes without it. Simultaneous measurements of meteorological variables were also made. The sampling and analytical methods used were the revised U. S. National Institute for Occupational Safety and Health (NIOSH) chromotropic acid procedure and Pro-Tek C-60 passive dosimeters.

The results by both methods showed a seasonal relationship between indoor air and wall cavity formaldehyde concentrations which was positive for outdoor temperature and absolute humidity. However, some homes responded differently to seasonal variables than others. While all homes containing UFFI showed variations in wall cavity formaldehyde, only about 60 percent showed corresponding room air fluctuations. These were described as UFFI-Responders. Those which did not show the relationship were called UFFI-Nonresponders. Wind direction and velocity showed a positive correlation with formaldehyde concentrations in wall cavities for both responder and nonresponder homes. Construction factors were assumed to be responsible for the differences between responder and nonresponder homes but were not identified.

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INTRODUCTION

In the latter part of 1980, increasing concerns about the health effects of formaldehyde gas led to a temporary ban on UFFI, in Canada, late in 1980. This ban became permanent in April 1981. Soon after, a grant program was instituted by the federal government. Initially, eligibility for assistance, in any individual case, was to be based upon a demonstrated concentration of one tenth of a part per million (0.1 ppm) of formaldehyde. This condition, which was later dropped, had been adopted as a provisional standard by the government and was based upon a recommendation from Health and Welfare Canada. The same value had also been recommended as a ceiling concentration by the American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE)[1].

After the introduction of the home-owner assistance program, large scale testing of formaldehyde in homes began to take place. Most of this was initiated by the federal government but private consultants and similar organizations were also involved. In 1981, the University of Western Ontario Occupational Health and Safety Resource Centre (OHSRC) tested over 100 homes, for their owners, in London, Ontario. About 30 percent of these showed formaldehyde concentrations in excess of 0.1 ppm.

A noticeable feature of these tests was that formaldehyde concentrations were generally lower in the fall and winter. This was demonstrated, also, when the same homes were repeat-tested as shown in Table 1. To confirm these findings, the study, reported here, was conducted jointly by OHSRC and the UFFI-Unit of the National Research Council. This test program was started in the summer of 1982 and completed by summer in 1983. It involved testing of 32 homes on six occasions, including the autumn and winter. The total sample of 32 homes consisted of 26 in which UFFI had been installed and six others which had never contained UFFI. These six were used as controls. All of the control homes were less than five years old when the survey started. This period was selected as it was approximately equivalent to the age of the urea-formaldehyde foam insulation in the homes selected for the study.

SURVEY METHODS

Organization

The formaldehyde testing schedule was programmed in six series in August, October and December 1982 and January, April and July 1983. These have been identified, here, as Series 1 to 6. In each series, two room air formaldehyde measurements were made in single-storey homes and four in two-storey homes. Wall cavity formaldehyde tests, using both Draeger and Gastec detector tubes at approximately 10 feet intervals, were also made in the outside walls of the UFFI-insulated homes. After initial tests had shown no detectable concentrations of formaldehyde in the wall cavities of control homes, further testing of these was abandoned. The meteorological parameters, measured, were outdoor temperature and humidity, wind direction and speed and barometric pressure.

Before testing, the occupants of the homes were asked to keep windows and doors closed, as far as possible, for approximately 18 hours. They were also asked to refrain from using air conditioners and ventilation fans and from cooking, smoking and operating motor vehicles in attached garages for the same period.

Sampling and Analysis

Indoor air samples were collected and analyzed by the modified NIOSH method proposed by Miksch[2], Active Oakridge Sieve Tubes (AORST) and three commercially available passive dosimeters. The three commercial dosimeters were the Pro-Tek C-60, the Air Quality Research (AQR) PF-1 and the 3M, Series 3750. The active NIOSH and AORST procedures showed good agreement with each other and with the three dosimeters. Actual comparisons of the results of the methods are to be published elsewhere and for the present paper only, the NIOSH and Pro-Tek results are used.

For the modified NIOSH method, samples were collected by midget impinger, containing one percent sodium bisulphite solution, for 4-hour periods at one litre per minute air flow rates. The bisulphite solution has been shown[3,4] to possess good sample stability, after collection, without refrigeration. Actually, all samples were refrigerated and analyzed within 1-3 days for this project.

The reliability and accuracy of the NIOSH method for low concentrations of formaldehyde have been the subject of differing reports. One recent study indicated the method was accurate and reliable providing it was employed in association with a standardized sampling and analytical protocol[5]. A sensitivity of about 0.01 ppm was also reported[6]. On the other hand, an error analysis performed on the results of an extensive Canadian survey indicated an uncertainty of 38 percent at 0.1 ppm formaldehyde[7]. This study cast considerable doubt on the validity of any results of less than 0.1 ppm.

In the OHSRC study in London, Ontario, great care was taken with the sampling and analytical procedure. All pumps were calibrated before and after each use and the results were discarded if differences of more than 5 percent between the two values were measured. A fresh calibration of the analytical method was also carried out for every batch of samples.

The passive dosimeters (Pro-Tek C-60) were exposed for 7-day periods. Both the NIOSH sample and the Pro-Tek C-60 were taken on the windward and leeward sides of each house. For two storey houses, two dosimeters were placed on each floor in rooms other than kitchens, bathrooms and laundries. All dosimeters were hung from the ceilings at least 50 cm from walls at approximately human breathing height. After exposure, all dosimeters were dispatched immediately to another laboratory (IEC Beak Consultants Ltd.) for analysis. Field unexposed blanks were submitted in conjunction with every sample and four laboratory blanks were also included with each batch.

Wall cavity formaldehyde analyses were made by Draeger and Gastec detector tubes. These tests were performed from inside the homes through holes bored in the lower parts of walls at 10 feet intervals around the home perimeters. By sampling from inside, the usual loss of sensitivity of the detector tubes at low temperatures was removed. Samples were also collected on the windward and leeward sides by the NIOSH method.

RESULTS

Formaldehyde in Room Air

When the results of the formaldehyde in air analyses were examined, only 15 of the 26 UFFI-homes showed a response to seasonal change. The remaining eight started at about 0.05 ppm in the first test series and did not change appreciably throughout the survey. For identification purposes, the two sets

of homes were termed "responders" and "nonresponders". A third set consisting of the remaining three UFFI-homes from which the foam had been removed earlier in the survey, were termed "UFFI-removed".

Thus, the homes were classified, as follows:

Controls:	Homes in which UFFI had never been installed;
UFFI-Responders:	Fifteen UFFI homes which showed an obvious seasonal change in room air formaldehyde concentrations;
UFFI-Nonresponders:	Eight UFFI homes which showed no clear evidence of a seasonal change in formaldehyde;
UFFI-Removed:	Three UFFI homes from which the foam had been removed after the second series of tests. Five other foam removals occurred after the fifth series but were left in their original classifications for the summary calculations.

The average concentrations of room air formaldehyde and other data are given for the modified NIOSH method in Table 2 and for Pro-Tek C-60 dosimeters in Table 3.

Figures 1 and 2 also show the series averages for the four classifications. Both figures show evidence of seasonal effects for the UFFI-responder classification but none for the other three. Statistical analysis indicated that only the UFFI-responder classification had significant differences between any pairs of series.

Comparisons between the different series, measured by the NIOSH method, indicated significant differences between August-September, 1982, and December, 1982 ($p<0.05$), between August-September, 1982 and January, 1983 ($p<0.05$) and between January, 1983, and July, 1983, ($p<0.05$). The results obtained by Pro-Tek C-60 dosimeters showed the same comparisons between equivalent pairs but in addition indicated significant differences ($p<0.05$) between both October, 1982 and November, 1982, and both December, 1982, and January, 1983, ($p<0.05$).

The very high Series 6 results (July 1983), shown for House 4, in both Tables 2 and 3 probably occurred because the house was closed and unoccupied for several months prior to the test. Also, on the day of NIOSH test (Table 2), the outdoor temperature was unusually high.

The differences between the UFFI-responder and UFFI-nonresponder averages were significant ($p<0.01$) only in Series 1 (Aug., 82) and in Series 6 (July 83). In the case of the Control home classification, the results were notable in that their measured formaldehyde concentrations were only exceeded by the UFFI-responder homes. For the first five series, the Control home average formaldehyde concentrations exceeded both the UFFI-nonresponder and UFFI-removed classifications.

Wall Cavity Measurements

Arithmetic average wall cavity formaldehyde concentrations, measured by Draeger and Gastec tubes, are given in Figure 3. Control homes which showed no detectable wall cavity formaldehyde concentrations were not included in the table. It is apparent that seasonal wall cavity trends occurred for all homes in which UFFI was installed. By contrast to the absence of a room air seasonal trend for Nonresponders, one clearly existed for wall cavities. Significant

seasonal differences were found for both the Responders and the Nonresponders and the trends were very similar for both groups. For the three UFFI-removed homes, the expected reduction in wall cavity formaldehyde concentrations, to below detectable level, occurred soon after the foam was taken out.

METEOROLOGICAL DATA

The meteorological variables which were considered as possible influences on formaldehyde concentrations were:

a) temperature
b) humidity
c) wind direction
d) wind velocity
e) barometric pressure

Temperature

The average outdoor temperatures varied through approximately 20°C in Series 1 (Aug., 82), 10°C in Series 2 (Oct., 82), 0°C in Series 4 (Jan., 83), 4.5°C in Series 5 (Apr., 83) to 23°C in Series 6 (July, 83). Temperature - room air formaldehyde plots for UFFI-responders, Nonresponders and Controls are shown in Figure 4. Statistical analysis of the results shown in the figure gave a positive correlation ($p<0.02$) only for the UFFI-responder classification. Though a positive relationship between temperature and formaldehyde concentrations for the Control classification also appears to exist in Figure 4, it was not statistically significant.

Equivalent values for the wall cavity formaldehyde concentrations corresponding to the temperatures measured are shown in Figure 5. Analysis of these results indicated a strong correlation ($p<0.001$) between temperature and formaldehyde for both UFFI-responder and UFFI-nonresponder homes.

Humidity

Outdoor relative humidity readings for the various seasons showed no substantial changes. They were about 10-15 percent higher in winter than in summer. No trends between formaldehyde concentrations and relative humidity were found though regression analysis showed slight positive correlations between relative humidity readings and formaldehyde concentrations for all classifications, but they were not statistically significant.

Wall cavity formaldehyde concentrations indicated no correlation with outdoor relative humidity for UFFI-responders, but the UFFI-nonresponders were significantly negatively correlated ($p<0.05$). This latter correlation was assumed to be adventitious.

On the other hand, absolute humidity was found to be significantly correlated with room air formaldehyde concentrations for the UFFI-responders, but not for any of the three other classifications. These results were similar to the formaldehyde - outdoor temperature comparisons. This was to be expected as the conversion of relative humidity to the absolute values involves temperature only. Similarly, wall cavity concentrations for the UFFI-responder, UFFI-nonresponder and UFFI-removed correlated positively ($p<0.01$) with absolute humidity values.

Wind Direction and Velocity

Formaldehyde measurements were made on the windward and leeward sides of homes. A total of 522 individual air samples, half each on the windward and leeward sides, were collected for the complete survey. The same number of windward-leeward wall cavity measurements of formaldehyde were also made. The wall cavity test sites were those which had been selected for a comparison measurement between the modified NIOSH method (to be reported elsewhere) and the detector tubes. Only the detector tube results are given here.

For the 522 room air samples, the arithmetic average results on the windward and leeward sides were identical at 0.057 ppm. In the individual series, it was apparent that no relationship between room air formaldehyde concentrations and wind direction existed. By contrast, the wall cavity formaldehyde results were consistently higher on the leeward than the windward sides. This was apparent in every series but only in Series 3, for UFFI-responder homes, was the difference found to be significant ($p<0.05$). In no other series, nor in the results for all six series, was a significant difference found.

In the case of wind velocity, a negative, but not significant, correlation was found for room air results in the Control, Responder and Nonresponder classifications. When the wall cavity results were compared with wind velocity, a strong negative correlation ($p<0.001$) for the UFFI-responder classification was found. The significance level was the same for both the windward and leeward sides. For the UFFI-nonresponder classification, the wall cavity formaldehyde concentration results indicated a negative correlation with wind velocity which was very close to being significant ($p<0.05$). The results for the wall cavity formaldehyde - wind velocity comparison for UFFI-responders are shown in Figure 6.

Barometric Pressure

A regression analysis of barometric pressure readings taken at the times of testing indicated a slight negative relationship, but it was not statistically significant. It was concluded that no relationship existed. Very rapid pressure changes would be more likely to cause short-term changes in formaldehyde concentrations, but it was not possible to include a study of these in this survey.

House Physical Effects

A number of correlations were attempted to determine whether such factors as house age, type and materials of construction, and the UFFI installation date and contractor had any effect on the room air or wall cavity formaldehyde concentrations. The only relationship found was that second floor readings were higher, on average, than the first floors of two-storey houses. Though the difference was appreciable, it was not statistically significant.

DISCUSSION OF RESULTS

This study indicated that a correlation between formaldehyde concentration in homes and changing seasons could occur. Significant differences in formaldehyde concentrations were measured between the summer values (1982 and 1983) and the intervening winter. The relationship was confirmed for both room air and wall cavity concentrations, the latter being more clearly sensitive to seasonal change.

An, as yet, unexplained factor caused some homes to behave differently to

others insofar as their room air concentrations showed a comparatively marked seasonal change while a smaller number of others did not. In the survey, those that showed a significant response were termed UFFI-responders and the others were called UFFI-nonresponders. Both types of house showed similar and marked seasonal fluctuations in wall cavity formaldehyde although the UFFI-responder concentrations were somewhat higher.

It would seem reasonable to assume that a relationship would exist between room air and wall cavity concentrations. Indeed, in this study, a correlation was found for UFFI-responders but not for UFFI-nonresponders. Had there been a relationship for the UFFI-nonresponders, a seasonal room air fluctuation in formaldehyde could have been expected for these. The correlation might have been expected to be less clear than for the UFFI-responders, but, in fact, it was nonexistent. From these observations, it could be inferred that a house construction factor may have been responsible for the difference between the Responders and Nonresponders.

Homes selected as Controls for comparison with UFFI-homes, were found to contain formaldehyde almost to the same degree. While none of the Controls ever had UFFI installed, their room air formaldehyde concentrations were higher than the Nonresponder UFFI homes and only marginally lower than the Responders. The formaldehyde in the Controls, for which only new homes were selected, probably originated from various types of resin bonded wood products. All Control homes were less than 5 years old. In addition to outdoor temperature, a correlation with indoor formaldehyde levels was found for outdoor absolute humidity. A study of an office building[6] also reported fluctuations in formaldehyde concentrations of about two to one between warm and cold weather.

Neither wind direction nor velocity were significantly correlated with room air formaldehyde. On the other hand, a consistent positive relationship for UFFI-responders, between wall cavity and the leeward room air was found. This correlation was only statistically significant for one of the six series. By contrast, a strong negative correlation was shown to exist between wind velocity and wall cavity formaldehyde concentrations on both the windward and leeward sides of homes for the UFFI-responder classification. A similar, but weaker, correlation for UFFI-nonresponder homes also existed.

CONCLUSIONS

The conclusion of this study was that outdoor temperature had an influence on room air and wall cavity formaldehyde concentrations in most, but not all homes, containing UFFI. Some showed a marked fluctuation in both room air and wall cavity formaldehyde, but in others the variation was in the wall cavities, only. These differences were considered to be true but the reasons were not fully identified. Unfortunately, by the time the data were analyzed and the responder-nonresponder difference became apparent, many homeowners had begun to remove the foam and make structural changes in their homes. This largely removed the possibility of determining the exact causes for the difference. The most likely explanation for responder/nonresponder effects was considered to be caused by differences in the sealing between the wall cavities and the rooms. If this is correct, it confirms that more effective sealing is one means of reducing room air formaldehyde levels in UFFI homes.

It was predictable that wind velocity would be negatively related to formaldehyde concentration, but it was only found to be statistically significant for wall cavities. If any correlation occurred for room air, it was a weak one. Wind may have the effect of lowering the wall cavity values on the windward side. This was partially confirmed by the observation of a positive

leeward to windward ratio for formaldehyde although the correlaton was not strongly significant.

The presence of formaldehyde in homes not containing UFFI at concentrations which were near to those which did contain the foam, could be worthy of further investigation. The presence of other products containing urea-formaldehyde was shown by the lack of a seasonal effect on room air concentrations. If formaldehyde in concentrations of about 0.1 ppm is a cause of adverse health effects, its presence in homes, such as the Controls used in this study, may be a cause for future concern.

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TABLE 1

REPEAT TESTING OF FIVE HOMES BY THE MODIFIED NIOSH METHOD SHOWING VARIATIONS OF INDOOR FORMALDEHYDE CONCENTRATION WITH SEASONAL CHANGES OF TEMPERATURE & HUMIDITY

HOME	DATE/TEST	OUTDOOR TEMP. °C	OUTDOOR R.H.%	LIVING RM. ppm	KITCHEN ppm	BEDROOM ppm
1	1981 08 20	24	55	0.14	0.12	0.15
	1981 10 29	9	65	0.04	0.04	0.04
	1982 02 02	-5	68	0.03	0.03	0.03
2	1981 07 02	27.5	65	0.15	0.09	0.12
	1981 11 13	6	50	0.07	0.07	0.07
	1981 02 04	-9	90	0.06	0.07	0.05
3	1981 09 03	25	57	0.15	0.16	0.13
	1981 10 30	14	62	0.07	0.07	0.05
4	1981 08 04	28	59	0.11	0.10	0.12
	1981 11 13	9	75	0.03	0.04	0.03
	1982 02 02	-5	68	0.03	0.06	0.03
5	1981 08 31	26	64	0.16	0.15	0.16
	1981 10 29	10	65	0.07	0.11	0.06
	1982 02 24	-7	67	0.04	0.03	0.02

TABLE 2

ARITHMETIC MEAN VALUES OF ROOM AIR FORMALDEHYDE CONCENTRATIONS IN HOME CLASSIFICATIONS INDICATED AS MEASURED BY THE NIOSH METHOD

HOME NO.	AGE (YR)	UFFI INSTALLED*	FORMALDEHYDE CONCENTRATION (ppm) TEST SERIES 1 Aug.82	2 Oct.82	3 Nov.82	4 Jan.83	5 Apr.83	6 July 83
A. CONTROL								
27	1	Not	0.06	0.05	0.05	0.06	0.05	0.07
28	5	Not	0.08	0.09	0.05	0.05	-	-
29	<1	Not	0.09	0.09	0.09	0.05	0.07	-
30	2	Not	0.05	0.04	0.02	0.02	0.03	0.05
31	1	Not	0.02	0.03	0.06	0.03	0.02	0.00
32	1	Not	0.05	0.06	-	-	-	-
B. UFFI-RESPONDER								
1	24	S.1979	0.07	0.06	0.05	0.05	0.06	0.05
2	41		0.07	0.04	0.02	0.01	0.03	0.04
4	3	F.1979	0.15	0.15	0.06	0.06	0.12	0.61
7	21	F.1976	0.07	0.02	0.04	0.03	0.02	0.08
11	25	S.1979	0.07	0.05	0.05	0.05	0.06**	0.03
12	75	Sp.1979	0.05	0.05	0.04	0.03	0.05	0.02
13	56	F.1980	0.09	0.10	0.08	0.06	0.07	0.16
15	18	Sp.1979	0.10	0.09	0.07	0.06	0.07	0.07
16	30	W.1979	0.06	0.02	0.03	0.02	0.01**	0.01
17	29	W.1977	0.04	0.02	0.02	0.03	0.02	-
18	40	F.1980	0.06	0.04	0.04	0.05	0.04	0.02
20	33	W.1980	0.07	0.07	0.04	0.04	0.06	0.07
22	75	F.1980	0.08	0.07	0.08	0.07	0.04**	0.04
25	95	F.1979	0.09	0.06	0.04	0.04	0.03	-
26	28	S.1980	0.09	0.08	0.06	0.05	0.07	0.14
C. UFFI-NONRESPONDER								
5	27	Sp.1980	0.04	0.04	0.04	0.04	0.03	0.07
6	45	Sp.1980	0.03	0.03	0.05	0.02	0.03	0.05
9	25	F.1977	0.05	0.05	0.07	0.06	0.07	0.07
14	31	S.1977	0.04	0.03	0.04	0.03	-	-
19	100	F.1979	0.02	0.02	0.02	0.02	0.01	0.03
21	45	Sp.1979	0.03	0.04	0.03	0.04	0.04**	0.02
23	32	Sp.1980	0.02	0.02	0.03	0.02	0.02**	-
24	40	S.1980	0.11	0.08	0.10	0.08	0.10	0.05
D. UFFI-REMOVED								
3	48	S.1978	0.04	0.03**	0.05	0.02	0.03	0.05
8	38	W.1979	0.04	0.05**	0.05	0.03	0.02	0.04
10	25	S.1977	0.02	0.04**	0.03	0.02	0.03	0.01

* S=Summer, F=Fall, W=Winter, Sp=Spring

**Foam removed between series indicated.

TABLE 3

ARITHMETIC MEAN VALUES OF ROOM AIR FORMALDEHYDE CONCENTRATIONS IN HOME CLASSIFICATIONS INDICATED AS MEASURED BY PRO-TEK C-60 DOSIMETERS

HOME NO.	AGE (YR)	UFFI INSTALLED*	FORMALDEHYDE CONCENTRATION (ppm)					
			1 Sep.82	2 Oct.82	3 Nov.82	4 Jan.83	5 Apr.83	6 July 83
A. CONTROL								
27	1	Not	0.04	0.06	0.06	0.06	0.06	0.04
28	5	Not	0.06	0.07	0.07	0.04	-	-
29	<1	Not	0.10	0.11	0.14	0.07	0.07	-
30	2	Not	0.03	0.03	0.03	0.03	0.03	0.05
31	1	Not	0.01	0.03	0.06	0.05	0.03	0.03
32	1	Not	0.03	0.05	-	-	-	-
B. UFFI-RESPONDER								
1	24	S.1979	0.07	0.05	0.06	0.04	0.04	0.05
2	41	S.1978	0.06	0.03	0.03	0.01	0.02	0.03
4	3	F.1979	0.26	0.09	0.06	0.04	0.06	0.48
7	21	F.1976	0.06	0.04	0.04	0.03	0.03	0.04
11	25	S.1979	0.05	0.05	0.07	0.04	0.04**	0.02
12	75	Sp.1979	0.04	0.04	0.05	0.03	0.03	0.02
13	56	F.1980	0.11	0.09	0.09	0.04	0.06	0.07
15	18	Sp.1979	0.08	0.06	0.07	0.04	0.07	0.07
16	30	W.1979	0.04	0.03	0.02	0.02	0.03**	0.02
17	29	W.1977	0.02	0.02	0.03	0.02	0.01	-
18	40	F.1980	0.06	0.04	0.06	0.04	0.05	0.03
20	33	W.1980	0.03	0.05	0.05	0.03	0.04	0.04
22	75	F.1980	0.04	0.07	0.07	0.06	0.05**	0.05
25	95	F.1979	0.05	0.07	0.06	0.05	0.04	-
26	28	S.1980	0.04	0.09	0.07	0.06	0.06	0.07
C. UFFI-NONRESPONDER								
5	27	Sp.1980	0.02	0.03	0.03	0.02	0.02	0.03
6	45	Sp.1980	0.03	0.04	0.04	0.02	0.03	0.05
9	25	F.1977	0.04	0.06	0.06	0.05	0.05	0.05
14	31	S.1977	0.05	0.03	0.04	0.03	-	-
19	100	F.1979	0.01	0.03	0.02	0.02	0.02	0.01
21	45	Sp.1979	0.03	0.04	0.04	0.04	0.04**	0.03
23	32	Sp.1980	0.02	0.03	0.02	0.02	0.02**	-
24	40	S.1980	0.07	0.09	0.04	0.09	0.10	0.06
D. UFFI-REMOVED								
3	48	S.1978	0.03	0.03	0.04	0.02	0.03	0.02
8	38	W.1979	0.04	0.04	0.04	0.03	0.03	0.03
10	25	S.1977	0.02	0.03	0.02	0.02	0.02	0.02

* S=Summer, F=Fall, W=Winter, Sp=Spring

**Foam removed after series indicated.

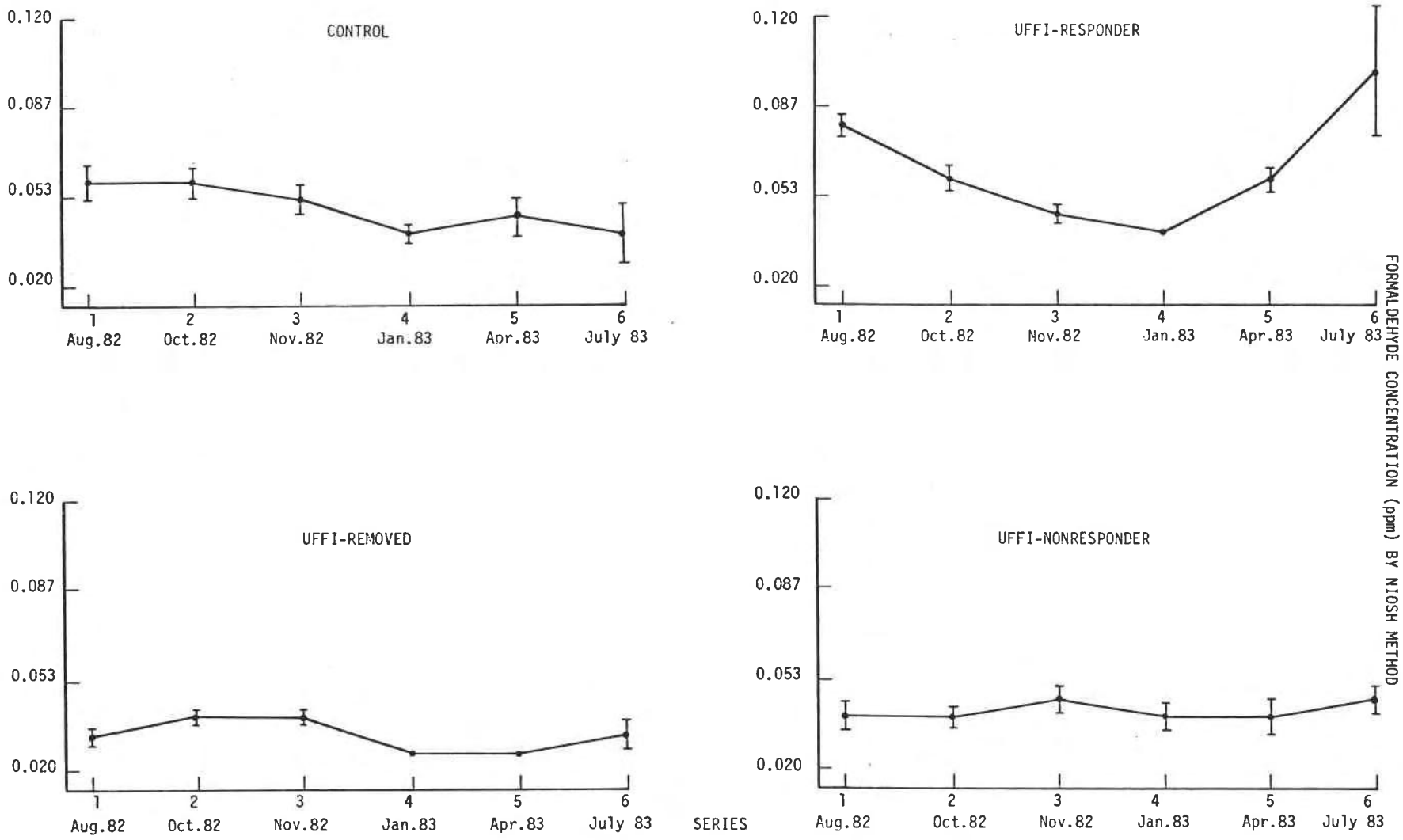

Figure 1. Mean room air formaldehyde concentrations for 6 test series in home classifications indicated.

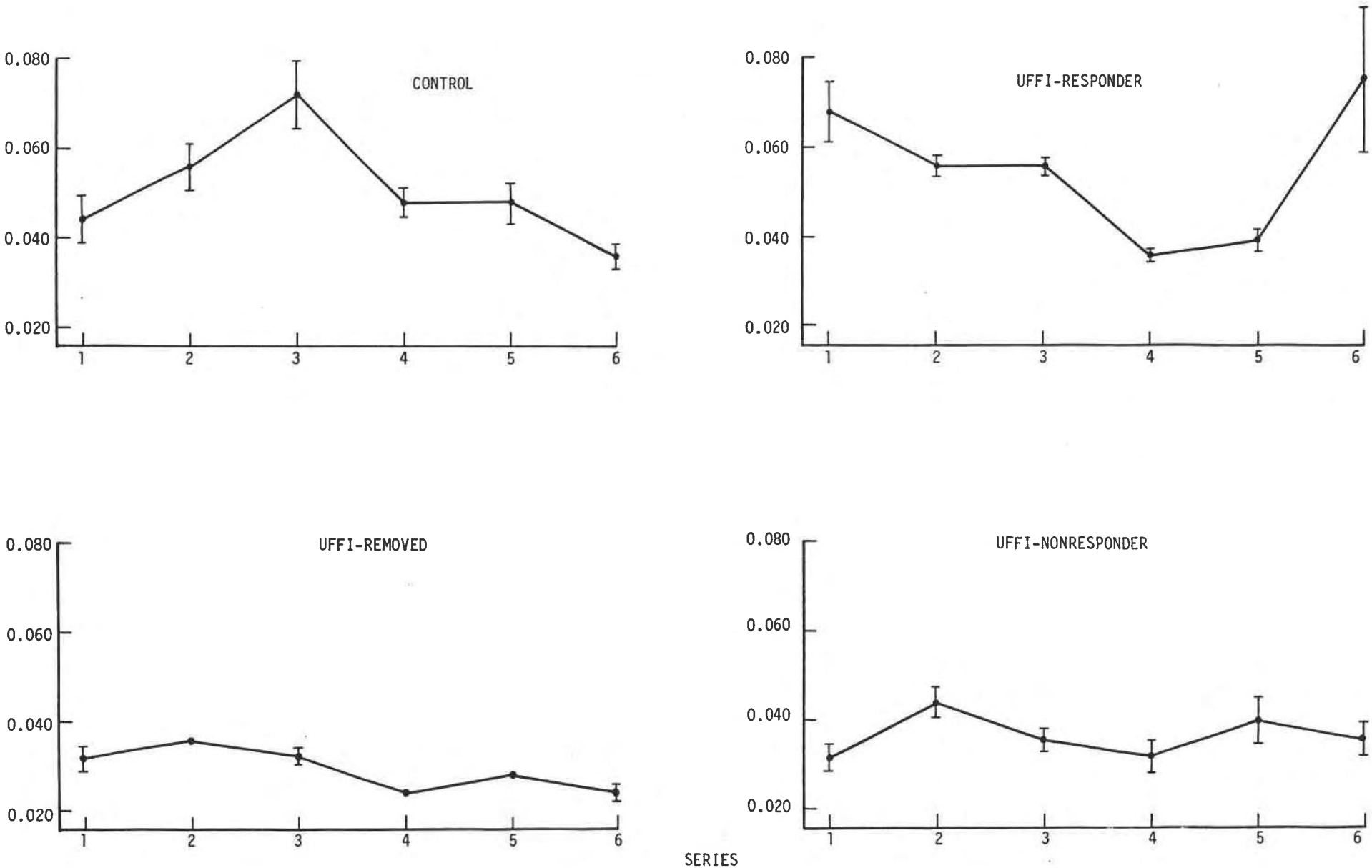

Figure 2. Mean air-borne formaldehyde concentrations for all 6 test series in home classifications indicated. (Pro-Tek C-60 Dosimeters)

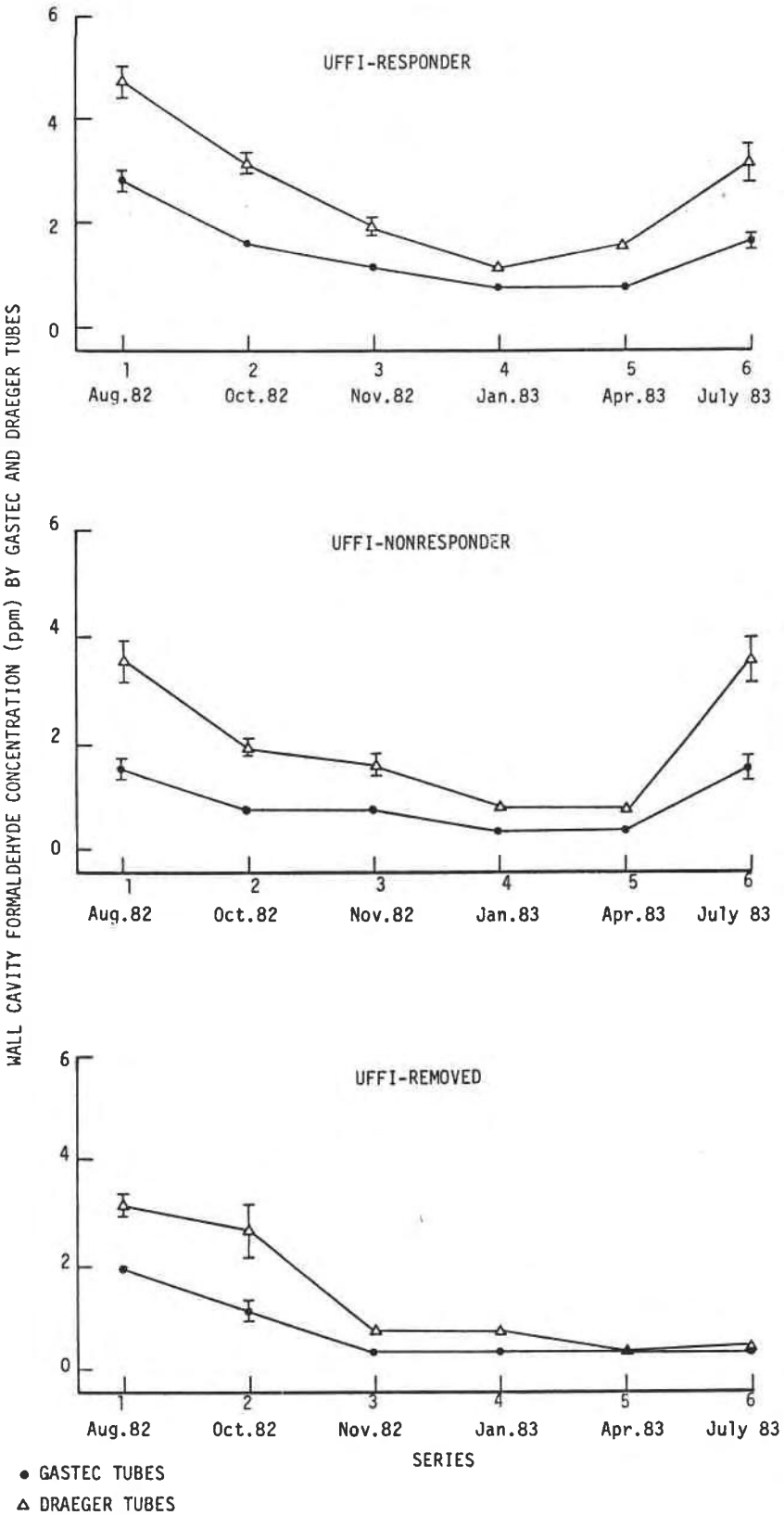

Figure 3. Mean wall cavity formaldehyde concentrations for 6 test series in home classifications indicated.

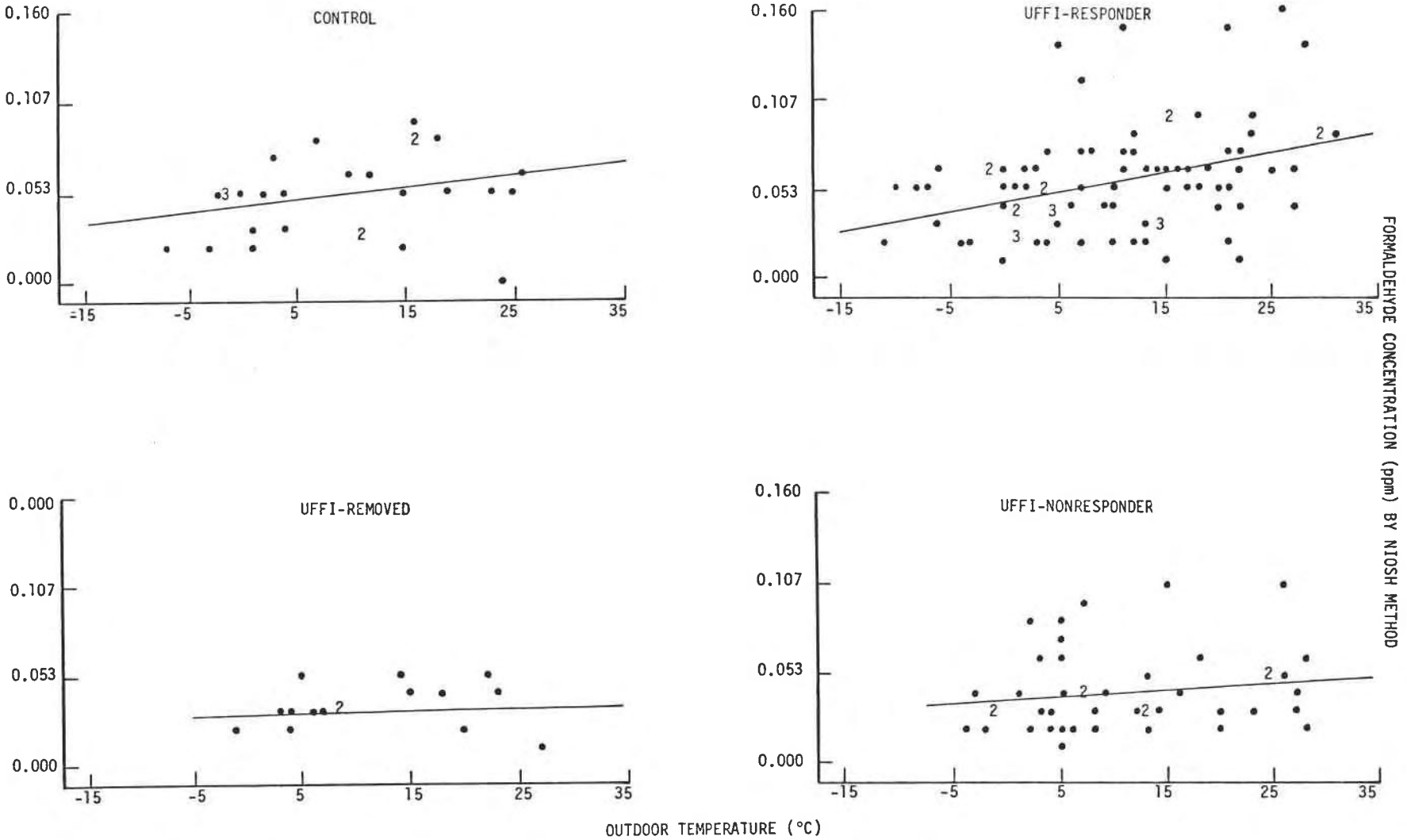

Figure 4. Relationship between room air formaldehyde concentrations and outdoor temperature.

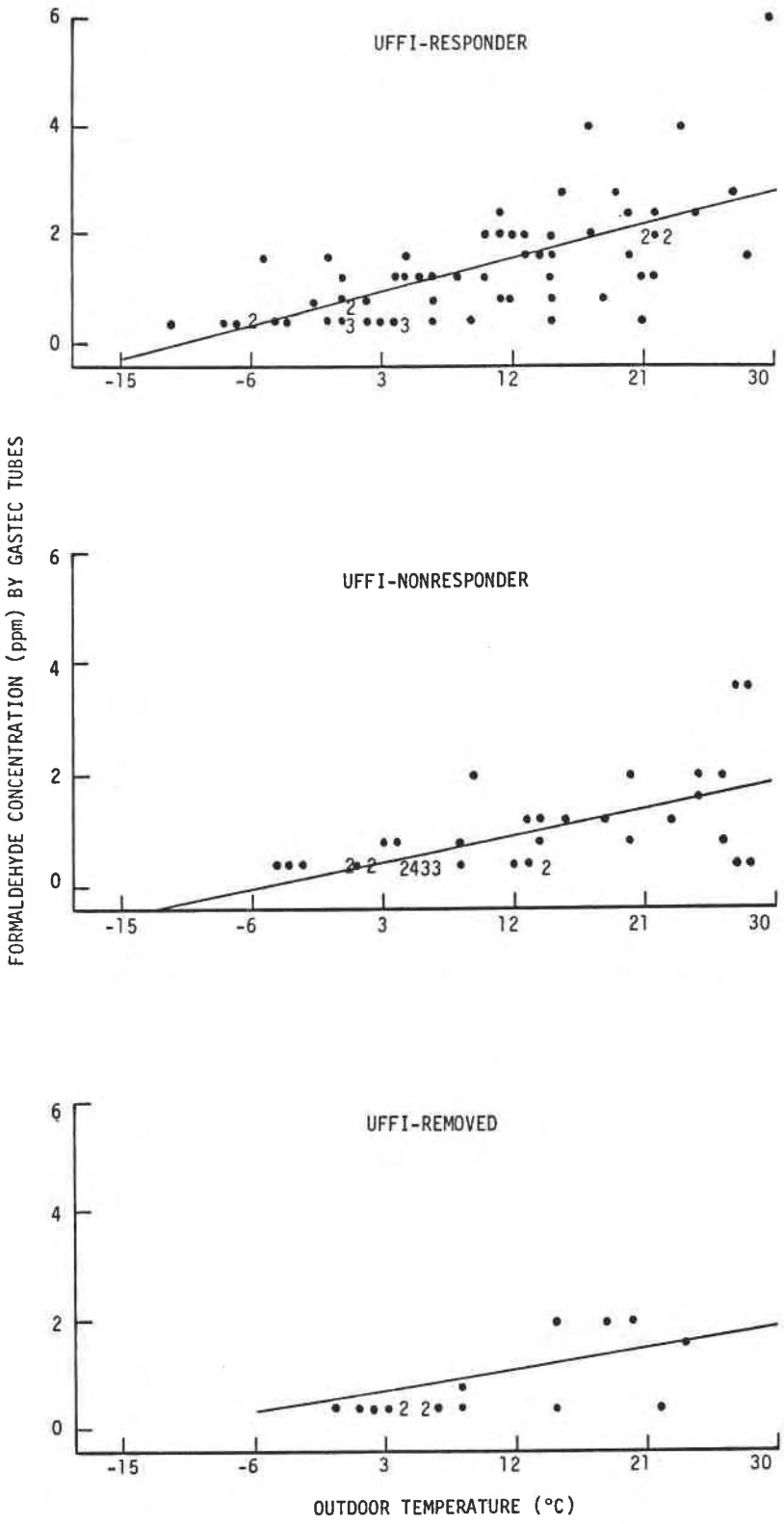

Figure 5. Relationship between wall cavity formaldehyde concentrations and outdoor temperature.

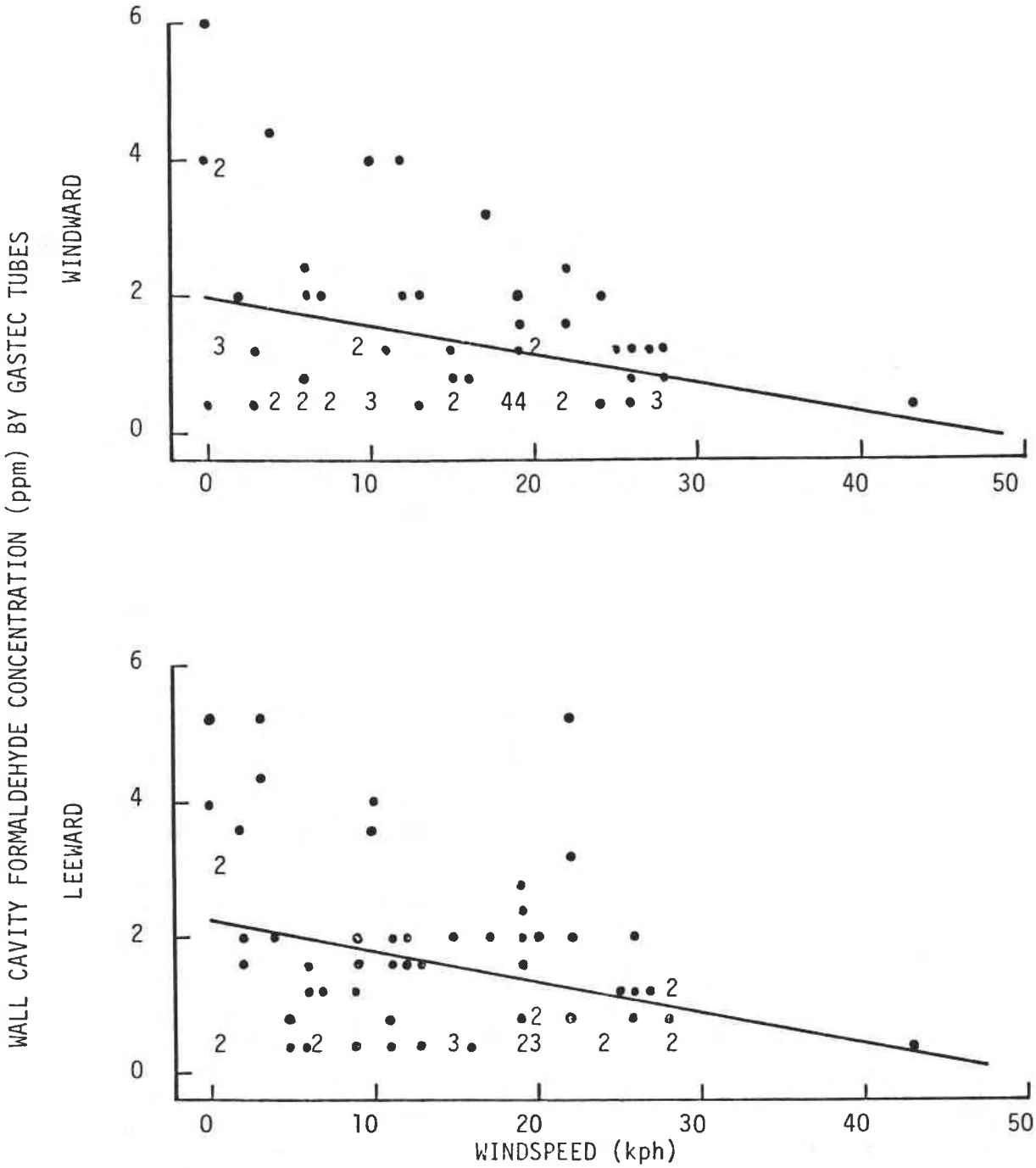

Figure 6. Relationship between windspeed and wall cavity formaldehyde concentration on windward and leeward sides of UFFI-Responder homes.