A STUDY OF FORMALDEHYDE IN A NEW OFFICE BUILDING

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ABSTRACT

A new four floor building with air conditioning on one floor and natural ventilation on the remaining three floors, was monitored for formaldehyde for fourteen months. Measurements were taken in 5 rooms on each floor to characterise factors affecting formaldehyde levels. The first measurements were taken directly after construction of the building through to 12 months of occupancy. In the new office building formaldehyde levels increased from a mean level of 9 ppb immediately after construction when no furnishings were present, to 29 ppb after carpet was added and to 49 ppb two months after the building was furnished and occupied. After occupation, levels fluctuated directly with outdoor temperatures. The lowest mean level of 31 ppb was measured during the coldest weather.

INTRODUCTION

Formaldehyde is a strong respiratory irritant (1) and a potential carcinogen (2). Formaldehyde has been reported as a contaminant of office buildings and has been associated with sick building syndrome, although the concentrations have generally been well below the parts per million level (3). Major sources of formaldehyde are pressed wood products such as particle board and plywood found in furnishings and panelling (4). Levels of formaldehyde in buildings have been found to be elevated as a result of emissions from furnishings (5).

Environmental factors are a major influence in determining levels of formaldehyde indoors. Levels of formaldehyde increase exponentially with an increase in temperature and decrease as a product of time (4).

METHODS

The building was a 4 storey office complex with large windows on each level facing onto gardens. The top storey, level 4, had air conditioning and levels 1, 2 and 3 relied on natural ventilation. The warm, Mediterranean type climate of Perth enables individuals to ventilate naturally by opening windows for many months of the year. On level 4, air was circulated in each room through ductwork installed in the ceiling and by supply diffusers. Rooms consisted of a combination of open plan areas and smaller enclosed offices. Most of the furniture in the building was new and included desks, bookshelves and cupboards constructed of particle board.

Formaldehyde was measured in the building over 540 days. Measurements commenced after the construction of the outer shell of the building, continued through six months of construction of the building and a further twelve months after furnishing and occupation of the building. The first measurements, day 0, were taken directly after construction of the outer shell of the building. At this stage there were few windows or doors installed in the building and no furnishings. The second measurements, day 30, were taken when outside ventilation was reduced in the building through the installation of all the doors and windows. The third measurements, day 68, were taken directly after carpets had been installed in many of the rooms. The fourth measurements, day 83, were taken one month later without further changes occuring to the internal structure of the building. The fifth measurements, day 203, and subsequent measurements, were taken at approximately monthly intervals for 12 months after all the rooms were fully furnished and occupied.

Monitoring was conducted using passive monitors for formaldehyde. Passive monitors were placed in the same locations in 5 rooms on each floor during monitoring. All monitoring was conducted on weekends to reduce the possibility of human influences.

The standard three section 37 mm aerosol cassette (Millipore Corp), was adapted to form a reusable passive monitor. The first section was left intact to act as a removable airtight protective cap. A teflon membrane with 1 mm pore size (Millipore FA 37) was chemically welded to the top of the middle section to act as a windscreen to eliminate air jets, yet the high surface porosity and thinness of the membrane offered little resistance to mass transfer (6).

Formaldehyde monitors developed for this study are based on the work by Levin *et al* (7,8). Uptake rate was calculated at 61 mL per minute and was not influenced by sampling time or relative humidity which is supported by Levin *et al.* (7). Sensitivity of the monitors were 1 ppb in a 24-hour sample and 3 ppb in an 8-hour sample (8).

100 mg of DNPH-HCL recrystallized twice from 4 M HCl was added to 1.7 ml of concentrated orthophosphoric acid (BDH AnalaR), 5 ml 20% glycerin (May & Baker) in ethanol and 90 ml of acetonitrile (BDH HPLC grade). 0.5 ml of the solution was added to each 37 mm diameter glass fibre filter, organic and binder free (Whatman GF/A). The filters were dried for 15 minutes in an oven at 40°C on a glass surface. Filters were put directly into the monitors and monitors sealed. Monitors were prepared on the day they were used and were sealed in air tight plastic bags. Formaldehyde blanks were less than 12 ug in each filter.

Formaldehyde 2,4-dinitrophenylhydrazone was eluted from the filter by shaking it for 1 minute with 4 ml of acetonitrile (BDH HPLC grade). 10 ul of this sample was injected for analysis by high performance liquid chromatography using 0.5 um reverse phase-18 column (MERCK liChroCART 125-4) with a mobile phase of 70% Methanol (BDH HPLC grade) in water. Hydrazone was detected with a Spectra-physics 2050 variable detector at 365nm. Retention time at a flow rate of 1 ml per minute was 2.9 minutes.

RESULTS

The mean concentration in the building on the first day of monitoring, day 0, was 9 ppb, when no furnishing or carpets were installed and many doors and windows were absent. Levels increased on day 30 to 13 ppb, after all windows and doors were installed and closed and the air exchange was reduced. Levels increased on day 68 to 29 ppb, when carpets were added to many of the rooms. Levels decreased slightly on day 83 to 23 ppb, although no changes had occurred in the internal structure of the building. On day 203, two months after furnishing and when the building was fully occupied, the highest level of 78 ppb was recorded and the highest mean of 47 ppb. These measurements were taken during Summer. Although no further changes in the structure of the building or its furnishings occurred, the levels of formaldehyde continued to fluctuate. Figure 1 and table 1 show mean temperature and formaldehyde concentrations in relation to the time after building construction.

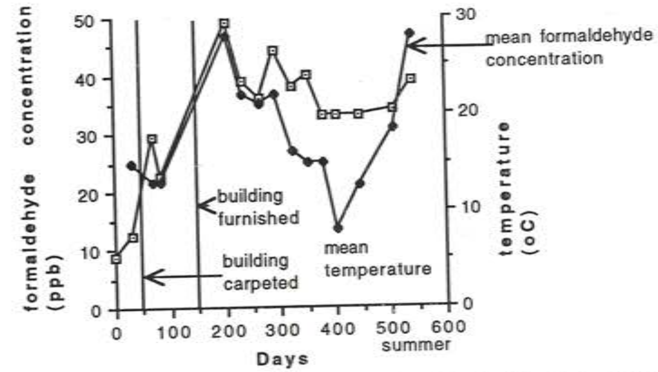

Figure 1 Formaldehyde and temperature fluctuations in a new building

Perth experiences a Mediterranean type climate with long, hot, dry summers and relatively mild, wet winters. A correlation coefficient of 0.707 (r^2 =0.499) was found between the fluctuations of the mean temperature fluctuations and the mean formaldehyde fluctuations.

Table 1 Formaldehyde and temperature fluctuations in a new building

Day of monitoring	Formaldehyde Concentration (ppb) Mean	Range	Mean Temperature (°C)	Comments
0	9	2-15	16	building shell only
30	12	8-19	15	windows and doors installed
68	29	12-41	15	carpet added
83	23	10-34	13	
203	47	15-78	28	furnished and occupied (Summer)
231	38	11-46	22	
263	35	10-50	21	
291	42	12-55	22	
323	37	8-55	16	
351	39	20-47	15	
379	31	11-50	15	(Winter)
401	32	10-52	8	
444	32	8-44	12.5	
507	33	10-45	18.5	(Summer)
540	37	11-61	29	

DISCUSSION

Mean levels of formaldehyde ranged from 47 ppb subsequent to the furnishing and occupation of the building to 31 ppb in mid winter six months later. These levels are consistent with levels reported in studies in the US in Oregon and Washington (9) and California (10).

Mean concentrations of formaldehyde increased from 9 ppb on day 0, to 13 ppb on day 30 when doors and windows were installed and closed. The restriction of ventilation caused a small increase in the levels of formaldehyde. This indicates the presence of a minor small increase in the levels of formaldehyde. This indicates the presence of a minor formaldehyde source in the building. After the addition of carpets on day 68, mean levels of formaldehyde increased to 29 ppb and showed a small decrease on day 83, although no changes had occurred in the internal environment of the building. A number of studies have found carpets to be a source of formaldehyde (5,11). Levels of formaldehyde increased from a mean concentration of 22 ppb with carpets, to a mean of 47 ppb on day 203 one month after the building was furnished and occupied, as shown in figure 1. Berk *et al* (12) found an increase of formaldehyde from 0.066 ppm to 0.183 ppm when new furniture was added to a research home. A number of studies have found furniture to be a major source of formaldehyde in buildings (5,12).

Temperature appeared to be a major factor in determining formaldehyde concentrations in the building. A correlation of 0.707 (r^2 =0.499) was found between mean temperature and mean formaldehyde concentrations.The lowest mean levels of formaldehyde were reported in mid-winter seven months after the building was furnished, and levels increased again in the summer. A number of studies have found concentrations of formaldehyde to be temperature dependent (13,14). As a result, formaldehyde has been found to have a significant seasonal variation, with higher levels in summer and lower levels in winter (14). Konopinski (15) reported formaldehyde concentrations in warm weather were twice the concentrations measured in cold weather in a one story office building.

Formaldehyde concentrations were found to be dependent upon time. Mean formaldehyde concentrations decreased most rapidly in the first months after the building was furnished. Concentrations decreased 21% from the highest level of 47 ppb in the first summer, to 37 ppb 12 months later. The release of formaldehyde from pressed wood products and other sources is known to decrease with time (4) with formaldehyde off-gassing greater in the first months of use (16). Previous studies have shown consistently that the highest indoor formaldehyde concentrations tend to occur in new buildings (10).

CONCLUSION

Major sources of formaldehyde in the monitored building were identified as carpets and furnishings. With the addition of carpets and furnishings formaldehyde concentrations increased. Temperature was identified as an important factor in determining the concentration of formaldehyde in the building, and elevated concentrations were associated with warmer outdoor temperatures. Levels of formaldehyde showed the greatest rate of decrease soon after the building was furnished. Over 12 months of monitoring the furnished building, levels decreased by 21% from a mean level of 47 ppb to a mean level of 37 ppb.

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