The Effects of Sealed Office Buildings on the Ambient Environment of Office Workers

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Abstract

We have recently completed a review of 116 investigated incidents of building illness among office workers in North America and 27 buildings selected for investigations for reasons other than building illness. Data extracted from these 143 studies form a valuable archive of information about the pollutant levels observed in buildings with and without persistent health and environment-related complaints.

One hundred and thirty-six different pollutants have been measured in more than one building. Pollutant levels in these buildings turned out to be no higher than levels measured in similar buildings with no record of health-related complaints. Also pollutant levels do not seem to be affected by office smoking policies. There is some evidence that relatively high levels of indoor organic fractions provide a source for the formation of irritating photochemical oxidants. This process may be enhanced by ultraviolet emissions of fluorescent lighting.

1. *Introduction*

Paralleling reductions in ventilation undertaken to conserve energy has been an increase of requests for health hazard evaluations initiated by occupants of sealed, air-conditioned buildings who believe their office or work environment to be hazardous and their symptoms to be building related. In fact, the term 'building illness' has been suggested for these incidents. A large number of reports from such investigations may now be available in the United States and Canada in addition to similarly motivated European and Japanese studies and present a potentially invaluable source of information on building ventilation, industrial hygiene measures, indoor air quality, health and occupant comfort.

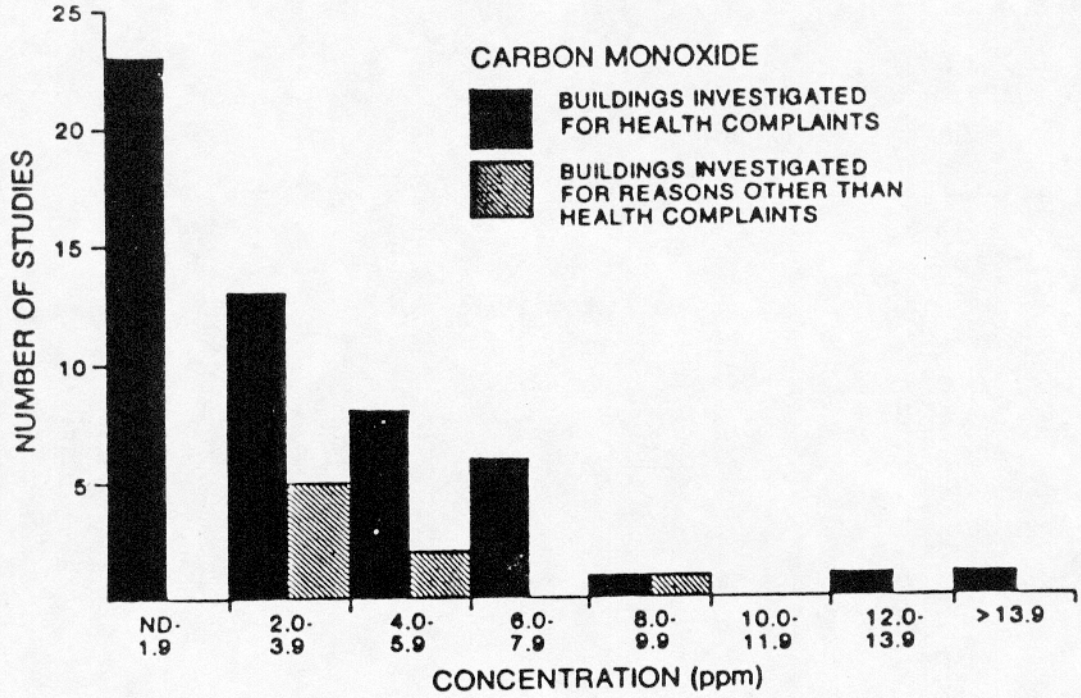
This report is based on the information obtained from 143 building studies made available through the US National Institute for Occupational Safety and Health, the Centres for Disease Control and other investigators.

2. *Air Quality in Working Buildings*

There are a small number of incidents of building illness for which a clear-cut cause can be established. Elimination of that cause also eliminates the health related complaints. Respiratory symptoms were related to toxic dusts left as detergent residues from industrial carpet shampoos (Kreiss, 1981). Burning eyes, coughing, breathing difficulties, nausea and dizziness were traced to formaldehyde off-gassing from interior materials (Makower, 1981). Possibly, the most notorious and dangerous examples have been outbreaks of Legionnaire's disease and hypersensitivity pneumonitis linked to viruses, bacteria and fungi from air ventilation and hot water systems (Broome, 1979; Salvaggio, 1979; Banaszak, 1970; Fink, 1971). However, most studies of incidents of building illness failed to locate a direct cause for the experienced symptoms of discomfort and illness.

Most studies of buildings with illness complaints seem to have explored the possibility that heightened levels of indoor pollutants were the cause of the problems and obtained a series of measurements of at least indicators of pollution levels such as carbon dioxide, carbon monoxide, formaldehyde, ozone and particulates. Similar measures were obtained also from buildings studied for reasons other than comfort or illness problems. Information contained in 143 such investigations has been extracted so far into a computer-based data archive. One hundred and sixteen investigations were undertaken of buildings troubled by health and comfort complaints and 27 investigations were conducted for research purposes. 132 different chemicals and 12 other observations such as noise or bacteria are cited at least once. The archive contains an adequate number of measurements for many pollutants to provide information on the pattern of pollutant levels found in modern sealed buildings.

FIGURE 1. *Carbon monoxide and buildings investigated for health complaints.*



The distributions of pollution levels of all buildings are strongly skewed toward low values. Distributions of observed concentrations of pollutants overlap between the 116 buildings investigated for health and the 27 buildings investigated for reasons other than health. Figures 1 and 2 show the typical distribution of concentrations and overlap for both carbon monoxide and particulates. Similar distributions of concentrations are observed for all other pollutants (not shown here). It may be concluded, therefore, that pollution levels in buildings investigated for health complaints do not differ from those found in buildings investigated for other reasons. For purposes here, all buildings are combined.

FIGURE 2. *Particulates and buildings investigated for health complaints.*

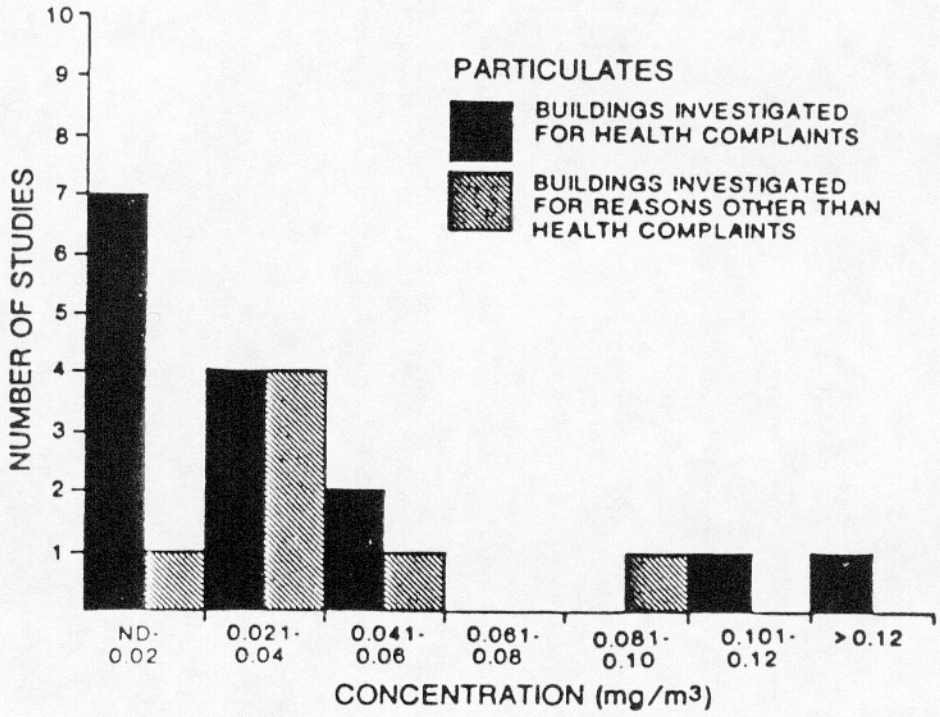


Table 1 presents information for those 16 most frequently measured pollutants from 143 buildings; it shows the number of buildings from which data points were obtained and the median levels measured. (Medians are given to adjust for the many reports of 'not detectable' (ND) levels, which in most cases may represent levels lower than the sensitivity of measurement procedures, and of 'trace', for which no value can be assigned.)

The average value of pollutants reported in modern buildings does not exceed levels deemed to be hazardous by occupational or industrial standards. Many occurred in such low levels that no detectable (ND) or barely detectable (trace) amounts could be found. The carbon monoxide median level was 2·54 p.p.m. based on 61 buildings. The carbon dioxide median level of 400 p.p.m. was based on 26 buildings. The particulate median level of 0·029 mg/m^3 was based on 22 buildings. Formaldehyde was measured in 44 buildings with

a median value of 0·02 p.p.m.. In general, measured levels of indoor pollutants were no larger than those already reported in the literature. The many reports that have measured but not detected various pollutants indicate that these pollutants occur, if they do, in values not now considered hazardous. The same is true of the many other pollutants measured in only one or two buildings and not listed in Table 1.

TABLE 1. *Average levels of 17 pollutants measured most frequently in buildings investigated for health complaints.*

Pollutant	All buildings	Number of reports
Acids	ND[a]	14
Aldehydes[b]	ND	8
Amines	ND	10
Ammonia	ND	9
Aromatic hydrocarbons[c]	Trace	55
Carbon dioxide	400 p.p.m.	26
Carbon monoxide	2·54	61
Formaldehyde	0·02 p.p.m.	44
Hydrazine	ND	6
Hydrogen sulphide	ND	9
Hydrocarbons	Trace	77
Metals	Trace	8
Nitrous and nitric oxides	ND	31
Nitrogen dioxide	ND	13
Ozone	ND	27
Particulates	0·029 mg/m^3	22
Sulphur dioxide	ND	20

[a] Where the median equals ND or trace, over 50% of investigators tested for that pollutant and reported ND or trace amounts.
[b] Not including formaldehyde.
[c] Hospitals not included here.

Contaminant levels in buildings with and without smoking restrictions were also compared to determine the added burden tobacco smoke might contribute to indoor air quality. Both comparison of median levels and of detailed graphs of range distributions (not shown here) showed no significant difference between buildings where smoking was allowed and where it was restricted or prohibited (Table 2).

3. *Discussion*

All buildings with health related complaints were sealed structures depending on mechanical ventilation and air-conditioning for thermal comfort and air quality and all appear to be lit by fluorescent lights. One possible hypothesis explaining the incidents of building

related symptoms occurring in some sealed buildings is that, as in a sealed test tube, the many pollutants present, especially hydrocarbon vapours, interact and combine to create irritating byproducts similar to photochemical smog. Smog measured outdoors has been shown to be associated with a symptom complex similar to that reported in building illness studies, especially the ever present eye, nose and throat irritation. Photochemical smog also has been shown to be related to many of the same vapours, nitrates and enzymes found inside buildings (Altshuller, 1978). It is also known that the formation of photochemical oxidants is accelerated by ultraviolet light. Many fluorescent lamps in buildings have detectable ultraviolet emissions (Duro Test Corp., 1978).

TABLE 2. *Average levels of 17 pollutants measured most frequently in buildings investigated for health complaints categorized by smoking restriction.*

Pollutant	Buildings with no smoking restrictions	Number of reports	Buildings with smoking restrictions	Number of reports
Acids	ND	13	ND	1
Aldehydes[a]	ND	7	0·052 mg/m^3	1
Amines	ND	10	–	0
Ammonia	ND	8	ND	1
Aromatic hydrocarbons[b]	Trace	54	0·82 mg/m^3	1
Carbon dioxide	440 p.p.m.	23	613 p.p.m.	3
Carbon monoxide	2·31 p.p.m.	52	4·0 p.p.m.	9
Formaldehyde	0·021	39	ND	5
Hydrazine	ND	4	ND	2
Hydrocarbons	Trace	75	ND	2
Hydrogen sulphide	ND	8	ND	1
Metals	Trace	7	ND	1
Nitrous and nitric oxides	ND	29	13 p.p.b.	2
Nitrogen dioxide	ND	13	–	0
Ozone	ND	23	0·015 p.p.m.	4
Particulates	0·036 mg/m^3	20	0·021 mg/m^3	2
Sulphur dioxide	ND	17	0·011 p.p.m.	3

[a] Not including formaldehyde.
[b] Hospitals not included here.

Recent measurement studies by Turiel *et al.* (1982), Hicks (1980), and Hollowell and Miksch (1981) provide additional support by demonstrations that the number and concentration of organic contaminants in tight buildings with complaints exceeded that of outdoor air.

All the necessary conditions exist in offices to produce photochemical smog. Experimental evidence for formation of photochemical smog also is offered by Sterling and Sterling (1983). An office floor was experimentally manipulated. While eye irritation decreased in areas when either fresh air was increased or fluorescent lights were replaced, there was a

dramatic improvement when fresh air was increased and ultraviolet levels were reduced simultaneously. Eye irritation returned to previous prevalence when the original conditions of lighting and ventilation were restored.

4. *Conclusion*

There is a significant amount of information now available on the many architectural and engineering factors which affect the health and comfort of office workers. It is becoming evident that totally sealed buildings dependent on sophisticated mechanical systems have been unable to provide acceptable conditions for human occupation without unacceptable energy costs.

A new ergonomic architecture that is responsive to human health and comfort in addition to energy conservation, new technology and new materials is now required for design of office buildings fit for human occupation.

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