TYPICAL POLLUTANT CONCENTRATIONS IN PUBLIC BUILDINGS

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ABSTRACT

Indoor pollutant levels have been measured in a substantial number of office and other public buildings in North America and Western Europe since the mid 1970's. An archive of indoor pollutant levels in buildings under normal conditions of occupancy and operation has been assembled into a computerized Building Performance Database. This paper presents median values and ranges for pollutants, such as carbon dioxide, carbon monoxide, and formaldehyde, for which there are at least 20 data records. Histograms of indoor ambient levels are also given for relative humidity, temperature, and eight chemicals.

INTRODUCTION

Environmental conditions in a large number of office buildings have been investigated by both private and public agencies, frequently in response to complaints about poor indoor air quality. As of April 1988, the results of 389 building investigations of problem buildings, mostly from U.S. nonindustrial workplaces such as offices, hospitals, schools and other public buildings, have been abstracted and entered into a computerized Building Performance Database (BPD) (1). The database currently contains 2,475 measurements of 189 pollutants. The investigations were conducted between 1974 and 1987. The BPD contains, for each building where possible, architectural and engineering data, ventilation and thermal characteristics, materials and machinery used in the buildings, information about the occupants and the building use, and levels of gaseous and particulate compounds in the ambient air.

Data on temperature, humidity, and ambient levels of chemical compounds is abstracted into a separate report in the BPD for each area. Each area is a separate office, floor or other discrete unit in a building.

METHODS

A search of the BPD was conducted to identify all compounds (including temperature and relative humidity), for which there were 20 data records or more in the BPD. The maximum and minimum value and the median value for each of these compounds was determined. The mean value was not determined because of the large number of values which were below the detection limit of the method used in each individual study.

RESULTS

There were over 20 data records for 23 chemical compounds and for temperature and relative humidity. Table 1 gives the number of measurements,

Table 1: Minimum, Maximum, and Median Values for Temperature, Relative Humidity, and 23 Chemical Compounds

	Number of Measurements	Range Minimum	Range Maximum	Median
Temperature	139	15.5 C	27.1 C	22.8 C
Relative Humidity	141	13.3%	73%	40%
Alkanes	26	Trace	3.5 mg/m^3	Trace
Ammonia	31	ND[1]	9.5 ppm	ND
Asbestos	24	ND	0.04 f/c^3	ND
Benzene	27	ND	1.4 mg/m^3	Trace
Carbon Dioxide	104	ND	1438 ppm	513 ppm
Carbon Monoxide	241	ND	245 ppm	2.65 ppm
Formaldehyde	259	ND	1.9 ppm	0.01 ppm
Hexane	22	ND	1.9 ppm	ND
Hydrocarbons	98	ND	1656 ppm	0.246 ppm
Methanol	53	ND	1440 ppm	430 ppm
Methyl chloride	22	ND	0.83 ppm	ND
Nicotine	32	ND	43.7 mg/m^3	ND
Nitrogen Dioxide	49	ND	0.1 ppm	ND
Nitrogen Oxides	40	ND	26.3 ppm	ND
Organics	50	ND	15 ppm	ND
Ozone	96	ND	0.09 ppm	ND
Particles	85	ND	2.7 mg/m^3	0.04 mg/m^3
Perchloroethylene	21	ND	30.4 ppm	Trace
Sulphur Dioxide	46	ND	0.17 ppm	ND
Toluene	80	ND	6.3 mg/m^3	Trace
Trichloroethane	40	ND	61.1 ppm	Trace
Trichloroethylene	28	ND	2.7 ppm	0.001 ppm
Xylene	37	ND	10.1 ppm	0.003 ppm

[1] Not Detectable

the range, and the median value for each substance. Figures 1-11 provide histograms of the distribution of values for relative humidity and temperature and for nine chemical compounds of the greatest interest, ordered by the number of measurements: carbon monoxide, formaldehyde, carbon dioxide, particles, ozone, nitrogen dioxide, sulphur dioxide, nitrogen oxides, and nicotine.

DISCUSSION

The median values and ranges for the indoor pollutants listed in Table 1 and in Figures 1-11 provide benchmark data on the pollutant levels to be expected in the nonindustrial workplace. However, interstudy variability in the detection limit for specific substances could bias the estimated medians downwards, though the extent of any bias is not possible to determine. Variability in the detection limit occurs as a result of the use of different sampling methods. For example, the detection limit for carbon monoxide in a study which used Draeger tubes would be 5 ppm, whereas the detection limit in another study which used direct reading methods could be 1 ppm or less.

Figure 1

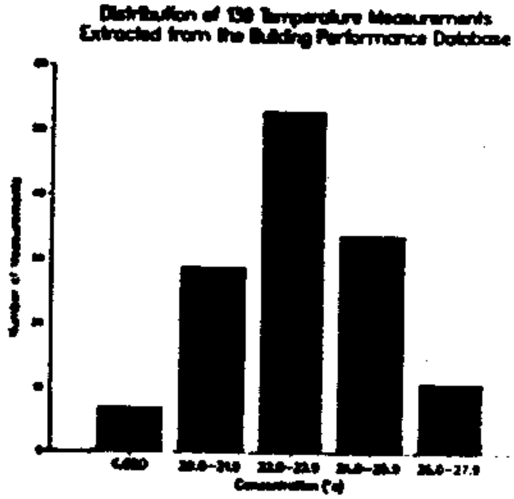


Figure 2

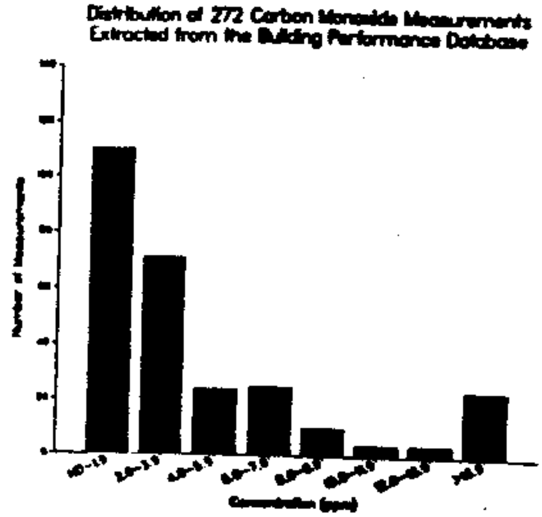
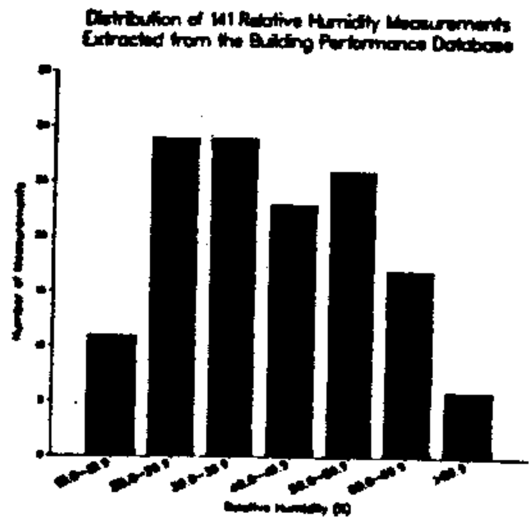


Figure 3



Though the data is not derived from a random or representative sample of buildings, the results should reasonably approximate the true median level for problem buildings that are investigated in response to occupant complaints of poor air quality. This is indicated by the fact that there has been relatively little change in the median value of 14 substances for which there were at least 10 reports in a 1985 study of BPD results based on a total of 143 reports (2) and the median value in this study based on 389 reports. For example, Table 2 compares median values from the 1985 study with those from this study.

A measurable change of over 5% of the 1985 median occurs for only three of the 14 substances. The greatest change was a 50% decrease in the median value for formaldehyde, from 0.02 ppm to 0.01 ppm. The decline may have partly been due to a decrease in the use of building materials which off-gas high levels of formaldehyde. The second and third largest changes are for carbon dioxide (+37.0%) and particles (+33.0%), respectively. However, there was very little change in the median value for temperature (+2.7%), relative humidity (+3.9%), and carbon monoxide (+4.3%).

Figure 4

Distribution of 250 Formaldehyde Measurements
Extracted from the Building Performance Database

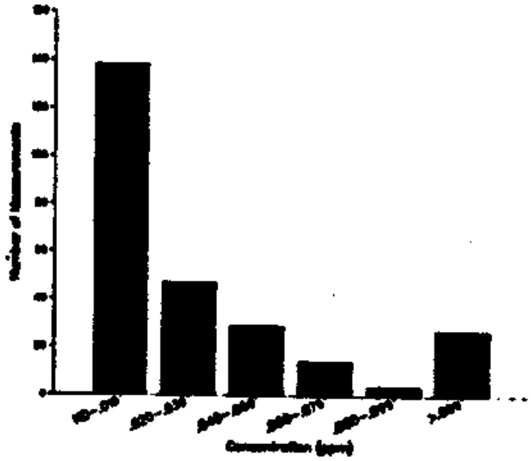


Figure 5

Distribution of 161 Carbon Dioxide Measurements
Extracted from the Building Performance Database

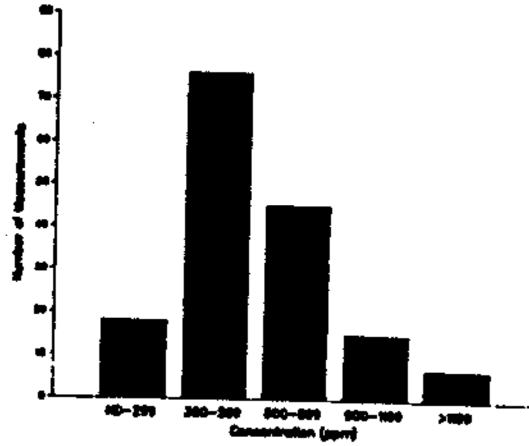


Figure 6

Distribution of 1[illegible] Particulate Measurements
Extracted from the Building Performance Database

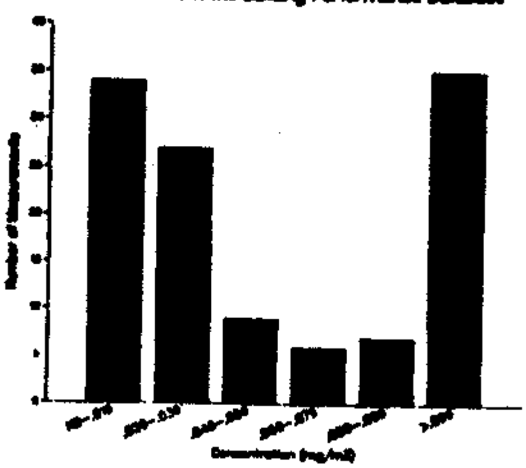


Figure 7

Distribution of 96 Ozone Measurements
Extracted from the Building Performance Database

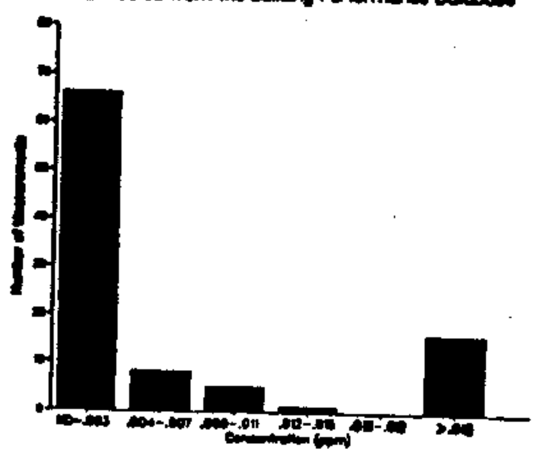


Figure 8

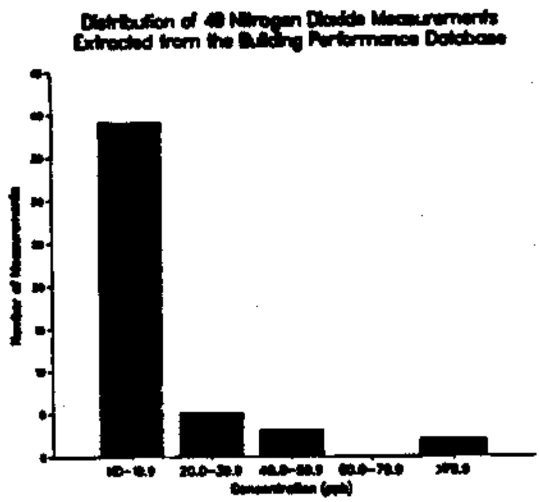


Figure 9

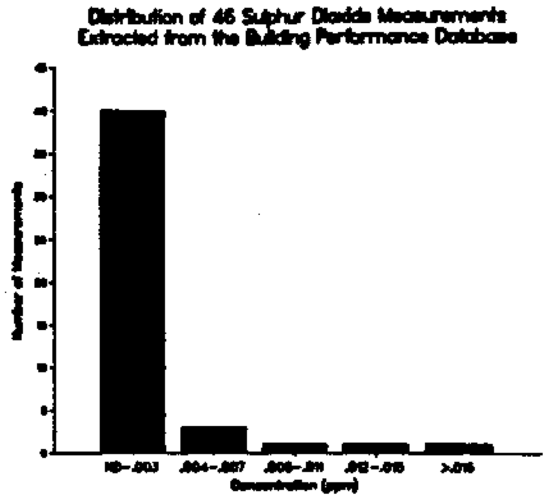


Figure 10

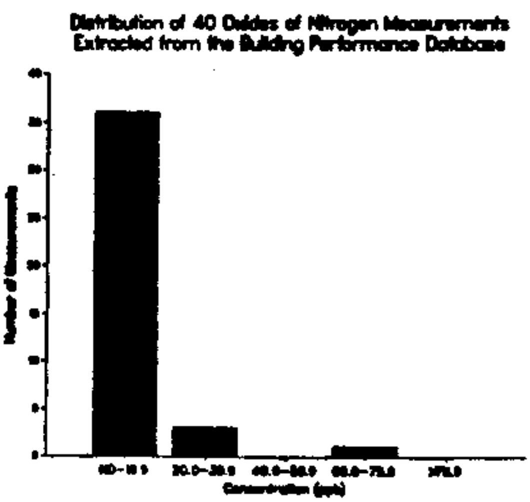


Figure 11

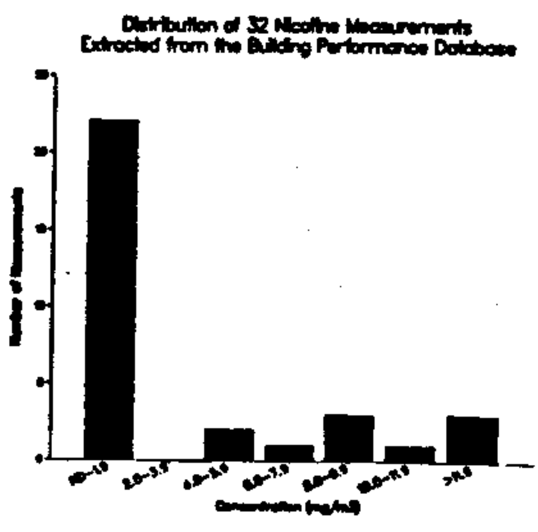


Table 2: 1985 and 1988 BPD Estimates of the Median Temperature, Relative Humidity and Indoor Pollutant level: Limited to Substances for which there were 10 or more Records (Rcds) in 1985.

	1985 # Rcds	1985 Median	1988 #Rcds	1988 Median	Percent Change
Temperature	26	22.2 C	139	22.8 C	+2.7
Relative Humidity	29	38.5%	141	40.0%	+3.9
Carbon Dioxide	26	400 ppm	104	513 ppm	+28.3
Carbon Monoxide	61	2.54 ppm	241	2.65 ppm	+4.3
Formaldehyde	44	0.02 ppm	259	0.01 ppm.	-50.0
Hydrocarbons	77	Trace	98	0.25 ppm	---[1]
Nitrogen Oxides	31	ND[2]	40	ND	NC[3]
Nitrogen Dioxide	13	ND	49	ND	NC
Organics	11	Trace	50	ND	---
Ozone	27	ND	96	ND	NC
Particles	22	0.03 ppm	85	0.04 ppm	+33.3
Sulphur Dioxide	20	ND	46	ND	NC
Toluene	23	0.015 mg/m^3	80	Trace	---
Xylene	10	Trace	37	0.003 ppm	---

[1] Indeterminate
[2] Not Detectable
[3] No Change

The histograms (Figures 1-11) can be divided into three groups. The distribution pattern for the first group, consisting of carbon dioxide, relative humidity, and temperature, approximates a normal distribution, with a central peak in the frequency. The first group consists of factors which are not pollutants, though both relative humidity and temperature affect comfort and carbon dioxide can be used as a marker for inadequate ventilation. The pattern for the second group, consisting of the pollutants carbon monoxide, formaldehyde, ozone, nitrogen dioxide, sulphur dioxide, nitrogen oxides and nicotine, generally shows an exponential decline or a "J" shaped curve, with the highest frequency of measurements in the not detectable range. This pattern is expected as a result of passive or active attempts to prevent or reduce indoor levels of these pollutants. The distribution pattern for particles differs from the other two groups in showing a marked "U" shaped curve. This may be a result of the division of many offices into areas where smoking is either permitted or restricted. However, the results for nicotine, an accurate indicator of the presence of smoking, do not indicate a "U" shaped distribution. It is also possible that the "U" shaped distribution for particles is a result of other factors, such as building renovations or street repairs which can substantially increase indoor particulate levels.

REFERENCES

1. Sterling, E.M., Steeves, J.F., Wrigley, C.D., Sterling, T.D., and Weinkam, J.J. (1985) Proceedings of the International Conference on Building Use and Safety Technology. March 12-14, 1985. National Institute of Building Sciences, Los Angeles, CA.
2. Sterling, E.M. and Sterling, T.D. (1985) Proceedings of the American Institute of Architects. Research and Design 85: Architectural Applications of Design and Technology Research. March 14-18, 1985, Los Angeles Calif. The American Institute of Architects Foundation.