AN EMPIRICAL STUDY OF HEALTH AND COMFORT OF WORKERS IN CONTEMPORARY OFFICE ENVIRONMENTS

E.M. Sterling
Theodor D. Sterling Ltd.
#70 - 1507 W. 12th Avenue
Vancouver, B.C. V6J 2E2 Canada

T.D. Sterling, Professor
Simon Fraser University
Burnaby, B.C. V5A 1S6

SYNOPSIS

A work environment survey questionnaire designed to test for and document perceived environmental conditions and prevalence of tight building syndrome symptoms among occupants of typical office buildings was administered to 1106 office workers in 9 office buildings in the New York City area. Buildings were screened for energy conserving retrofits and architectural and ventilation factors. Data were classified according to ventilation and thermal conditions, lifestyle and personal factors, use of modern office equipment, smoking regulations, and work-related stress.

Health and comfort related complaints were found to be associated with perceived environmental conditions (especially ventilation and lighting) and with the ability of occupants to control some environmental conditions, but not with regulations restricting or prohibiting smoking. Distributions of health and comfort judgements in these typical office buildings can serve as a base against which to compare responses of occupants in suspected problem buildings.

INTRODUCTION

New modes of design, construction, ventilation and energy management have had profound effects on indoor air quality in office and commercial buildings. Sealed, air-conditioned buildings, especially modern office buildings, contain a wide variety of pollutants often exceeding levels found outdoors. (Hunt et al, 1971; Spengler and Sexton, 1983; Sterling and Kobayashi, 1977; Sterling et al, 1982; Yocum, 1982) Occupants of these same buildings often also suffer from a complex of symptoms including headaches, burning eyes, irritation of the respiratory system, drowsiness, fatigue and general malaise, known as Building Illness or Tight Building Syndrome. (Baxter, 1980; Hicks, 1983) Many public health authorities believe tight building syndrome may be reaching epidemic proportions. For example, in the U.S. the National Institute for Occupational Safety and Health (NIOSH) alone has completed over 200 building investigations since 1974, 100 of which have occurred in the past two years. Nearly 50% of all outbreaks have been linked to inadequate ventilation.(Melius et al, 1984)

In the interest of energy conservation, building ventilation as well as lighting has been drastically decreased. As well, occupant control over both office ventilation and lighting has been reduced. New ventilation standards proposed by The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and the U.S. Department of Energy (DOE) recommend and permit a reduction of ventilation air by up to 90%. (ASHRAE, 1981; DOE, 1979) For example, the previous ASHRAE ventilation standard published in 1973 recommended 25 cubic feet per minute per person of fresh air ventilation in general office areas of air-conditioned office buildings. (ASHRAE, 1977) However, the new ASHRAE Standard, designed for energy conservation and published in 1981, requires only 5 CFM per person of fresh outside air provided smoking is either not allowed or is restricted to designated areas. (ASHRAE, 1981) This amounts to a five-fold reduction of ventilation requirements. Similar decreased ventilation standards are also being adopted in other countries.

Tight building syndrome experienced by occupants is often suspected to be a direct result of reduced fresh air ventilation. However, without comparative data it is difficult to determine whether the indoor environment experienced by occupants under reduced ventilation conditions is better or worse than under previous conditions. Most indoor air quality research and occupant health and comfort studies have been undertaken as a direct result of energy conservation. However, in

order to conserve energy and maintain building performance, architects and designers need to know how well buildings perform under normal conditions. The empirical data needed to compare occupant health and comfort complaints in buildings with reduced ventilation to complaints in normal buildings is now available from a detailed survey of 1,106 occupants of nine "normal" office buildings.

METHOD

A self-administered Work Environment Survey questionnaire designed to collect perceptions of environmental conditions and prevalence of building illness symptoms among office occupants was administered to 1106 office workers in greater New York City. As far as was known, there were no prior history of health and comfort complaints among the study group, no prior investigations of the office environments included, and no major energy conservation retrofits to the buildings.

The Work Environment Questionnaire requested information about: respondents, work related stress, environmental conditions, health-related symptoms and control over environmental conditions. In addition, information related to lifestyle and other possible environmental exposure was collected.

Questions were so constructed that they could be scored on a 3 point scale, with a 1 indicating a favorable, 2 an intermediate and 3 an unfavorable response. The distribution of responses for health and environment related questions were evaluated by constructing comprehensive indices which combined related and non-conflicting questions.

RESULTS

Table 1 presents the percent distribution of complaints about environmental conditions. Seventy-five percent of office workers reported too little air movement as opposed to only 35% reporting too much air movement "Sometimes or Often." Unpleasant odor, often used as an indicator of inadequate ventilation, was reported by 40% of respondents as occurring at least "Sometimes" and by 14% as occurring "Often or Always". Temperature was a consistent problem, with 77% reporting conditions too cold and 72% reporting conditions too hot "Sometimes or Often". Although 44% of respondents complained of smoky air in the workplace, 74% reported stuffy conditions. These results seem to indicate a need for more appropriate regulations or control by office workers of conditions affecting temperature and air quality. Current air quality regulations (ASHRAE, 1981) are based on restriction of tobacco smoke, however, from the survey results it would appear that an indicator of "stuffy air" such as carbon dioxide level rather than "smoky air" would be a better means of overall air quality control.

Lighting conditions were considered satisfactory. However, responses indicated that brightness and glare could be improved. Forty-three percent reported that lighting was too dim and 45% reported glare on work surfaces "Sometimes or Often." Lighting conditions are not now a significant problem among office workers, however, with illumination levels and window area being reduced to conserve energy, future problems could result.

Table 2 presents the distribution of building illness symptoms commonly reported in the indoor air pollution literature. Headache, fatigue, nose irritation and eye irritation (symptoms indicating general discomfort with environmental conditions) were reported most frequently. Thirty-seven percent of office workers reported headaches, 52% reported fatigue, 32% reported nasal irritation and 37% reported eye irritation more than once a week. Twenty-one percent of respondents reported sore throat or cold symptoms once a week or more.

In addition to basic frequency analysis, the distribution of responses for health and environment related questions were evaluated by constructing comprehensive indices that combined related and non-conflicting questions. Table 3 shows the indices used to assess overall effects of working conditions on health-related symptoms, and environmental conditions.

Health and Environment indices were cross-tabulated with responses to individual questions about the environment and control over the environment in order to determine the effect of such variables as ventilation, lighting, and tobacco smoke on the comfort of office occupants. Results of cross-tabulations are presented in two-dimensional tables. For example, Table 4 cross-tabulates the Building Illness Index (along the vertical axis) and responses to the question of "Too Much Air Movement" (along the horizontal axis). The total number of responses for each row and column are shown. The percent of overlapping responses are given in each cell. Chi Square

(χ^2) is shown at the bottom of the table along with the p value, unless p is not significant (i.e. $p>.05$).

Ventilation. Table 5 shows the association between conditions of ventilation in the workplace and building illness symptoms. There is a highly significant relation between poor ventilation and building illness. Forty-four point six percent of office workers with good ventilation as compared to 32.9% with poor ventilation did not complain of building illness. As fewer occupants of well-ventilated buildings complained of building illness symptoms, air movement and quality of ventilation appear to be major determinants of health and comfort among office workers.

Lighting. Table 6 shows the association between office lighting conditions and building illness symptoms. There is a highly-significant relation between poor lighting and building illness. Twenty-five point two percent of office workers with poor lighting ranked "poor" on building illness, while only 10.3% with good lighting did so.

Environmental Tobacco Smoke. Some of the workers surveyed smoked and some of them did not. Some of them worked in places where smoking was permitted, some in places where smoking was prohibited and some in places where smoking was restricted. Thus, a number of groups were constructed for comparison:

1. nonsmokers in a nonsmoking working zone,
2. nonsmokers in a smoking working zone,
3. smokers in a nonsmoking working zone, and
4. smokers in a smoking workers zone.

The effect of smoking on nonsmoking office workers is reviewed in the next two tables. Tables 7 and 8 show that there is no significant association between smoking at work and either building illness or visual health among office workers who either smoke or do not smoke.

Table 9 shows the association between Smoking at Work and the Odor Index. There is no significant difference in the perception of unpleasant odors among nonsmokers or smokers regardless of whether smoking was or was not permitted.

Control over Environment. In most modern office buildings control of air conditioning and lighting has been removed from office occupants. Tables 10 and 11 show the association between control by occupants of air conditioning and lighting and symptoms of building illness. There clearly is a significant relationship between control of air conditioning and incidence of building illness. In Table 10, 15.9% of office workers with no control of air conditioning scored "poor" on the building illness index compared to 4.8% of office workers with control of air conditioning. There is a similar significant relationship between control of lighting and incidence of building illness. In Table 11, 15.9% of office workers who had no control of lighting scored "poor" on the "Builidng Illness Index" compared to 6.7% who had control of lighting conditions. In both cases respondents who had control over conditions were approximately three times less likely to suffer symptoms of building illness than those with no control.

DISCUSSION

The results indicate that even among occupants of buildings operated under normal ventilation and lighting conditions, there exist problems with environmental conditions as well as a relatively high level of health and comfort complaints. There is a consistent pattern of association of factors relating both ventilation and lighting with frequency of reported illness symptoms. Office workers judging their ventilation and lighting environments as poor were more likely to have health complaints than those who considered ventilation and lighting to be good. Office workers with control over environmental and lifestyle factors such as controlling air conditioning, opening and closing windows, switching on and off lighting and smoking had fewer complaints about health and stress symptoms than did office workers with no control over environmental and lifestyle factors.

Very interesting is the lack of significant association between building illness, visual health and odor indices and exposure to environmental tobacco smoke. The findings here however do not relate to irritation due to smoking but the association of the absence or presence of smokers (or, at least, the permission or prohibition of smoking) to perceived health and/or comfort levels. This lack of association probably is due to two reasons. First, pollutant patterns depend heavily on ventilation factors, while at the same time, byproducts of combustion infiltrate or are generated and entrapped in a building from many sources. In fact, reviews of the published literature (Sterling and Kobayashi, 1977) and of pollutant levels reported in 143

buildings by NIOSH, the Center for Disease Control and other investigators (Sterling et al, 1983) fail to find differences in pollution concentration, or patterns in offices with and without smoking restrictions. Second, the manner of administering the questionnaire avoided calling attention to smoking (or any other) factors, besides including questions pertaining to them. It is especially interesting that there were no differences in respondents perception of odors between locations with and without smoking rules (Table 9).

This Work Environment Survey, though limited to office workers in greater New York City, provides some measure of human health and comfort with environmental conditions provided by contemporary office buildings. However, the majority of office buildings may now be designed and built to reduced environmental standards in order to achieve energy conservation goals. Also, many existing contemporary office buildings are being renovated and operated to reduce the amount of energy used. The human costs that may result from reduced environmental standards of energy conservation in office buildings are still unclear. This study presents empirical data showing the relation of environmental parameters to health and comfort of office workers in buildings prior to energy conserving adjustments or modifications. These questionnaire survey results can be used for comparison with similar data collected from occupants of energy conserving office buildings to provide background for prudent standards to ensure that energy efficient buildings are designed, built and operated to provide conditions acceptable for human occupation.

ACKNOWLEDGEMENTS

The study was made possible by the cooperation and support of members of Local 153, Office and Professional Employees International Union in greater New York City. We are also indebted to Diana Hartel-Kobayashi of the Columbia University School of Public Health for help with design, layout and administration of the Work Environment Questionnaire.

REFERENCES

ASHRAE Standard 62-73 (ANSI B 194.1-1977). "Standards for Natural and Mechanical Ventilation", American Society of Heating, Refrigerating and Air Conditioning Engineers, New York, 1973.

ASHRAE Standard 62-1981. "Ventilation for acceptable indoor air quality", American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, 1981.

Baxter, P.J. Paper on biological substances and indoor air quality prepared for the subgroup for health effects of indoor pollution. Proceedings U.S. Government Interagency Research Group on Indoor Air Quality: Workshop on Indoor Air Quality Research Needs, Leesburg, Virginia, December 3-5, 1980.

Department of Energy (DOE), Office of Conservation and Solar Energy, Energy Performance Standards for New Buildings: Proposed Rule, Federal Register, November 28, 1979.

Hicks, J.B. "Tight building syndrome", Occupational Health and Safety Magazine, (in press), 1983.

Hunt, C.M., Cadoff, B.C. and Powell, P.J. "Indoor air pollution status report", National Bureau of Standards Report, April 10, 1971, 10:591.

Melius, J., Wallingford, K., Keenlyside, R. and Carpenter, J. "Indoor Air Quality — The NIOSH Experience", Proceedings, Meeting of the American Congress of Governmental Hygienists, Atlanta, Georgia 1984.

Spengler, J.D. and Sexton, K. "Indoor air pollution: A public health perspective", Science, 1983, 221(4604):9-17.

Sterling, T.D. and Kobayashi, D. "Exposure to pollutants in enclosed living spaces", Environmental Research, 1977, 13:1-35.

Sterling, T.D., Dimich, H. and Kobayashi, D. "Indoor byproduct levels of tobacco smoke: A critical review of the literature", Air Pollution Control Association Journal, 1982, 32:250-259.

Sterling, T.D., Sterling, E. and Dimich-Ward, H.D. Air Quality in Public Buildings with Health Related Complaints", ASHRAE Transactions, 1983, 89(2A):198-207.

Yocum, J.E. "Indoor-outdoor air quality relationships", Air Pollution Control Association Journal, 1982, 32:500-520.

Table 1. Percent distribution of complaints about environmental conditions

Environmental Condition	Never or Rarely	Sometimes	Often or Always	Total %
Too Little Air Movement	25	39	36	100
Too Much Air Movement	65	29	6	100
Lighting Too Bright	77	15	8	100
Lighting Too Dim	57	28	15	100
Glare on Work Surfaces	55	30	15	100
Unpleasant Odors	46	40	14	100
Temperature Too Cold	23	54	23	100
Temperature Too Hot	28	56	16	100
Air Too Dry	35	43	21	100
Air Too Moist	73	25	3	100*
Air Too Smoky	56	31	13	100
Air Too Stuffy	26	47	27	100

* error due to rounding

Table 2. Percent distribution of symptoms commonly associated with building illness

Symptoms	Once a Month or Less	Once a Week	Once a Week or More	Total %
Headache	63	16	21	100
Fatigue	49	24	28	100
Nose Irritation	68	13	19	100
Eye Irritation	63	20	17	100
Sore Throat or Cold	79	13	8	100

Table 3. Groups of questions used to construct health and environmental indices

Health Indices

Visual
- . blurred vision
- . eye irritation
- . split or double vision
- . trouble focusing eyes

Cardiorespiratory
- . nose irritation
- . breathing difficulty
- . chest pain or tightness
- . racing heart

Musculoskeletal
- . neck ache
- . sore arms, hands, wrists
- . backache

Neurophysiological
- . headache
- . dizziness
- . fatigue
- . sleepiness
- . moodiness
- . depression
- . lightheadedness
- . confusion

Building Illness
- . headache
- . fatigue
- . nose irritation
- . eye irritation
- . sore throat or cold symptoms

Absenteeism
- . days absent during past six months
- . days left work due to illness in past six months

Medication
- . aspirin
- . stomach or digestive aids
- . cough, cold or sinus medication
- . stimulants (pep pills)
- . prescription medicine
- . laxatives
- . depressants
- . sleep inducing aids

Environment Indices

Lighting
- . lighting too bright
- . lighting too dim
- . glare on work surface

Ventilation
- . too little air movement
- . too much air movement
- . air too stuffy

Temperature
- . too cold
- . too hot

Humidity
- . too dry
- . too moist

Odor
- . unpleasant odor
- . too smoky

Table 4. Too much air movement

BUILDING ILLNESS INDEX	Never	Sometimes	Often	Number of Cases
Good	42.8	42.7	43.8	440
Average	41.3	47.0	37.5	439
Poor	16.0	10.3	18.8	149
Total	100%*	100%	100%	
Number of Cases	664	300	64	

$\chi^2 = 7.41$

Table 5. Ventilation Index

BUILDING ILLNESS INDEX	Good	Average	Poor	Number of Cases
Good	44.6	50.0	32.9	445
Average	44.6	41.4	45.2	461
Poor	10.8	8.6	21.9	153
Total	100%	100%	100%	
Number of Cases	195	430	434	

$\chi^2 = 44.72$ $p \leq .001$

Table 6. Lighting Index

BUILDING ILLNESS INDEX	Good	Average	Poor	Number of Cases
Good	46.7	43.9	30.5	443
Average	42.9	43.9	44.3	459
Poor	10.3	12.1	25.2	156
Total	100%*	100%*	100%	
Number of Cases	687	66	305	

$\chi^2 = 45.63$ $p \leq .001$

Table 7. Smoking at Work

BUILDING ILLNESS INDEX	Non Smoker No Smoking Work Zone	Non Smoker Smoking Work Zone	Smoker No Smoking Work Zone	Smoker Smoking Work Zone	Number of Cases
Good	37.9	43.1	43.0	38.9	312
Average	51.5	38.7	44.4	46.5	349
Poor	10.6	18.2	12.6	14.6	112
Total	100%	100%	100%	100%	
Number of Cases	66	137	151	419	

$\chi^2 = 5.30$

Table 8. Smoking at Work

VISUAL HEALTH INDEX	Non Smoker No Smoking Work Zone	Non Smoker Smoking Work Zone	Smoker No Smoking Work Zone	Smoker Smoking Work Zone	Number of Cases
Good	66.7	68.6	70.9	68.3	531
Average	24.2	16.1	17.9	20.5	151
Poor	9.1	15.3	11.3	11.2	91
Total	100%	100%	100%*	100%	
Number of Cases	66	137	151	419	

$\chi^2 = 4.19$

Table 9. Smoking at Work

ODOR INDEX	Non Smoker No Smoking Work Zone	Non Smoker Smoking Work Zone	Smoker No Smoking Work Zone	Smoker Smoking Work Zone	Number of Cases
Good	28.6	37.9	37.1	33.8	255
Average	58.7	47.7	56.6	53.3	392
Poor	12.7	14.4	6.3	12.9	87
Total	100%	100%	100%	100%	
Number of Cases	63	132	143	396	

$\chi^2 = 7.63$

Table 10. Control Air Conditioning

BUILDING ILLNESS INDEX	Yes	No	Number of Cases
Good	51.6	40.9	447
Average	43.5	43.2	458
Poor	4.8	15.9	155
Total	100%*	100%	
Number of Cases	124	936	

$\chi^2 = 12.17$ $p \leq .005$

Table 11. Control Lighting

BUILDING ILLNESS INDEX	Yes	No	Number of Cases
Good	46.0	41.3	449
Average	47.3	42.8	464
Poor	6.7	15.9	156
Total	100%	100%	
Number of Cases	150	919	

$\chi^2 = 8.80$ $p \leq .05$