DOES INDOOR AIR POLLUTION AFFECT OFFICE PRODUCTIVITY?

L.I. Baron, Ph.D.[1] and E.M. Sterling, B.Arch[2]

INTRODUCTION

The office, once considered a safe and comfortable alternative to the industrial site, is fast becoming a dangerous, uncomfortable and stressful environment. Among the various factors affecting white collar workers is the reduced quality of indoor air. Each year the number and intensity of worker complaints and disease outbreaks increases. Today an estimated 25 percent of the North American workforce can be found in office buildings. Sealed in mechanically ventilated buildings incorporating new principles of design and the use of new materials, products and equipment, office workers are now exposed to an increased level and variety of pollutants.

Why this phenomenon is only now becoming apparent can be directly tied to the energy crisis of the 70's. The rapid rise in energy costs ushered in the end of an era of high ventilation within sealed office buildings. With decreased ventilation and an increased incidence of disease there came a marked increase of requests for building health hazard evaluations initiated by the occupants who believed their office environment to be hazardous and their symptoms to be building related(1). In a few severe incidences the press became involved and buildings were actually closed.

While the direct health implications of decreased indoor air quality are generating more studies, the impact of this degradation of work environment upon work performance has not even been broached. We know that there exists a relationship between pollution and disease. We know also that health and productivity are related. But how does this particular degradation of a work environment affect efficiency? By performance we mean a whole variety of changes related to polluted air. The effects may vary. Persons may work more slowly and so produce less. Persons may also make more errors or if an element of danger is involved persons may be more liable to injury. After an accident or illness, persons may prolong their sick leave in order to delay returning to the stressful environment. And, finally, stressful working conditions have been found to increase the amount of absence from work.

What is needed is a reliable index, similar to outdoor air quality measures, that would link changes in the quality of indoor air to changes in performance and productivity. We need some yardstick to determine when to initiate and just how much alterations are needed to improve the physical environment of the office. Relying on subjective complaints of workers and the few documented incidences of major outbreaks are insufficient to guarantee a longterm healthy and safe work place.

BUILDING ILLNESS

A possible link between air quality and productivity might be provided by collecting more date on the incidence, intensity and ramifications

of a new malady most commonly referred to as Building Illness. Building Illness refers to widespread and persistent complaints of headaches, burning eyes, irritation of the respiratory system, drowsiness and fatigue within a given work space.

The types of Building Illness encountered to-date may be divided into two distinct categories. In one category the cause for the illness can be determined. Elimination of cause also eliminates health-related complaints. For instance, respiratory symptoms have been tied to toxic dust left as detergent residues from industrial carpet shampoos (2). Burning eyes, coughing, breathing difficulties, nausea and dizziness have been linked to formaldehyde off-gassing from interior materials (3). Outbreaks of Legionnaire's Disease and hypersensitivity pneumonitis have been linked to viruses, bacteria and fungi, from air ventilation systems (4,5,6,7).

In a second category studies of reported incidences of Building Illness have failed to identify a direct cause. Rather results of a recent study by Sterling et al (8) posit that:

(1) The average value of pollutants reported in buildings in which there were severe outbreaks of Building Illness do not exceed levels deemed to be hazardous by occupational or industrial standards set in Canada or the United States, and

(2) The observed levels of indoor pollutants does not seem to differ from measures reported from other buildings where symptoms of ill health and discomfort were not reported. Therefore, the cause of complaints probably does not lie in the level of pollution.

One likely hypothesis is that the non-specific symptom complex, especially the ever present eye irritation, is in part a reaction to indoor photochemical smog. Photochemical smog measured outdoors has been shown to be responsible for similar symptom complexes including eye irritation, headaches and respiratory problems. Photochemical smog has also been shown to be related to many of the same vapors found in modern buildings such as formaldehyde (off-gassing from particle board, insulation and other materials) and even trichloroethylene contained in white-out materials used by typists. (See references 9,10,11 for a detailed listing of materials linked to photochemical smog, and for lists of organics found inside buildings.) In addition modern office buildings are lit by fluorescent lights which give out variable amounts of ultraviolet radiation, a common catalyst for smog formation (12).

At what point may indoor smog become a relevant economic bottomline issue for office workers for public and private sector management and for the vendors and designers of office work places?

To-date most research quantifying the general incidence of office illness has been inadequate in identifying the level of indoor pollution that is critical to the creation of pathological symptoms that may affect productivity.

According to a study commissioned by Steelcase and conducted by Louis Harris and Associates, office comfort has a direct impact on the job

performance of white collar workers (13). A survey of work attitudes ranked more comfortable heat, air conditioning and ventilation as the second most important change that could help improve productivity. Knowing that if you produce more in a day you will be better paid ranked first at 48 percent of respondents while air quality rated a 45 percent response.

Workers do prefer to open their windows. Unfortunately, almost 2/3 of the office workers report that they are not able to open their windows. A plurality (46 percent) of the workers believe air circulation where windows can be opened is better than in offices where only the central heat and air conditioning systems circulate the air.

In another survey (14) of over 4,000 office workers and managers in about 50 public and private sector offices across the United States it was concluded that while air quality influences job and environmental satisfaction, it does not influence job performance. This conclusion, unfortunately, is not born out by the analysis. Perceptions of influences of air quality on performance were gleaned from interviews of office workers who were having their environments substantially changed. Changes included either moving or renovations. Air quality was not monitored. Overall, employees reported no change in problems with air quality following their move. However, employees reporting fewer problems with air quality after moving also reported an increase in environmental satisfaction. Based solely upon this data it is difficult to conclude that air quality does not affect productivity. Office changes surveyed may not have involved indoor air quality thus office workers may be equally satisfied (dissatisfied) with equivalent levels of air quality.

A work environment survey of 1100 office workers in nine different buildings in the New York City area conducted in 1982 provides the most complete analysis to-date of health and comfort in modern office buildings (15,16). Buildings were selected with no prior history of health or comfort problems. A questionnaire was designed to inventory comfort complaints and health related symptoms similar to those recorded for epidemics of building illness. It was found that uncomfortable conditions in the office environment were more prevalent than had been expected. Fifty-eight percent of respondents worked in sealed buildings. Seventy-five percent reported too little air movement, 54 percent reported unpleasant odors, over 70 percent reported that the temperature was either too cold or too hot, 65 percent reported the air too dry, and 74 percent reported the air too stuffy. Within these environments building illness symptoms experienced more than once a week were also prevalent: 37 percent reported headaches, 51 percent reported fatigue, 59 percent reported sleepiness, 31 percent reported nasal irritation, and 34 percent reported eye irritation. The study, however, stops short of measuring the influence of these factors on the office worker's performance.

ENVIRONMENTAL EFFECTS ON PERFORMANCE

The research studies to-date awaken us to the smoke in the air, the occasional epidemic reported in the press cries fire, but as yet there is no concrete move towards the creation of sound policy to remedy the problem. The studies are incomplete. If left at this stage there are risks that unsatisfactory policies relating to the office environment will result. Perception of changes in productivity by worker and supervisory ratings as well as reported symptoms among sufferers of stuffy air have not been linked to quantitative measures of changes in indoor air quality. We now have a rather crude on/off policy switch. At a certain unspecified level of discomfort both workers and their supervisors perceive that satisfaction and/or performance is affected. What that level is and the affect on productivity is unknown. Given the present state of knowledge, indoor air quality remains only a relevant policy issue when serious complaints are documented in clinically verifiable epidemic outbreaks. This, however, limits causal relationships only to a minority of reported complaints: those that have an identifiable polluting agent. In most investigated buildings, however, specific causes for symptoms have not been determined.

For a whole range of contaminant levels and mixes we have no clear idea of how the surpassing of specific limits will affect efficiency, susceptibility to accidents and attendance at work. If we could determine a relationship between degrees of lost performance and increases in indoor air pollution we would then be able to provide sound policy recommendations that delineate the required architectural modification to existing and new structures and their concommitant costs. The statistical foundation for cost/benefit studies would then be set.

Losses in productivity could be matched with the physical costs of alterations. We would be able then to determine the break even point that links air quality and performance to various proposed architectural and engineering modifications.

The demand for such a study fits well with a whole litany of research that measured productivity (various) in adverse environments. Over the past 40 years a whole range of work environment variables have been studied quantifying how incremental changes in a particular environmental variable influences performance. Heat, cold, light, noise, compression, mental work, overload, isolation and danger are but a few of the environmental conditions studied. In these studies a fall in efficiency was reflected in a number of different ways. For 22 environmental conditions, measures now exist that attempt to delineate contaminant levels and the kind of deterioration in performance that results. Conditions looked at to-date are heat, cold, dim light, glare, noise (continuous, intermittent, interference) vibration of man, motion of man, acceleration, weightlessness, decompression, compression, carbon monoxide, alcohol, sleeping tablets, loss of sleep, mental work overload, temporary exhaustion, detail work, isolation and danger (17). From this compilation of environmental conditions it is clear that for a whole range of working environments quantitative limits have been identified, the exceeding of which is likely to result in a fall in

efficiency, an increased susceptibility to accidents and a reduced attendance at work.

In recent research Rotton observed that malodor impaired performances on complex but not simple tasks (18). Exposure also produced behaviour aftereffects in the form of lowered tolerance for frustration when subjects had been deprived of control. Aftereffects increased with duration of exposure. The door thus opens on the linkages between the most innocuous effects of indoor air pollution and productivity.

In an experimental study of office workers exposed to low levels of stress caused by lighting and ventilation, Sterling observed no decrease in performance. This is consistent with the psychological literature that finds evidence for slight improvement of performance under minor conditions of stress (19).

Rotton and Sterling thus agree that low levels of ergonomic stress have no effect on simple tasks.

What remains to be done is to quantify and compare levels of complexity of task with levels of pollution related to both short and long term office productivity.

CONCLUSION

Without accurate measures of productivity losses due to Building Illness it is highly unlikely that the problem will be addressed on anything but an ad hoc epidemic specific level.

The cost implications of guaranteeing a tolerable level of indoor air quality for all buildings may be enormous.

> "Our demonstration of the possible formation of photochemical smog indoors and the relief of eye irritation following increased ventilation indicates that the one major cure for problems of modern, sealed buildings may be a high rate of ventilation. The same conclusions emerge from the demonstration of an association between building ventilation characteristics and the frequency of building-related complaints. Unfortunately, the cost of vigorous ventilation of modern, sealed buildings is high and it may well be that the so-called "energy conserving" building, as presently designed and ventilated, will end up being not so energy conserving at all." (20)

Without verifiable indicators relating indoor air pollution levels to performance, the tendency will be to discount whereever possible complaints and manifest symptoms by branding reactions as being limited to a minority hypersensitive population, thus relieving pressures to alter the environment for the majority of the "normal" non-complaining and supposedly unaffected workforce.

When fuel costs accelerated in the 1970's there were immediate pressures to conserve our non-renewable fossil factors of production. Subsidy programs were immediately introduced and building standards al-

tered. Now the human costs of these changes are being felt. It is highly unlikely, however, that there will be heavy subsidy programs that will stimulate the conversion of modern, sealed buildings into well ventilated structures suitable for the employment of human factors of production. Rather, without more evidence linking indoor air quality and productivity it is more likely that office workers will be forced to bear the cost of discomfort, illness and increased risk of longterm permanent health problems. As the longterm effects of exposure to indoor smog eventually take their toll society will bear the costs of higher prices for products, a greater degree of public sector inefficiency and an eventual increase in demands for medical services.

References:

1. Sterling, T., Sterling, E., The Epidemiology of Building Illness, Presented at the Second International Symposium on Epidemiology in Occupational Health, Montreal, August 23-25, 1982.

2. Kreiss, K., Gonzalez, M.G., Conwright, K.L. and Scheers, A.R., Respiratory irritation due to carpet shampoos, Proceedings International Symposium on Indoor Pollution, Health and Energy Conservation, University of Massachusetts, Amherst, Massachusetts, October 13-16, 1981.

3. Mikover, J., Office Hazards: How Your Job Can Make You Sick, Tilden Press, Washington, D.C., 1981.

4. Broome, C.V. and Fraser, D.W., Epidemiologic aspects of Legionellosis, Epidemiologic Reviews (1): 1-16, 1979.

5. Salvaggio, J.E. and Karr, R.M., Hypersensitivity pneumonitis: State of the art, Chest (75): 270-274, 1979.

6. Banaszak, E.F. et al, Hypersensitivity pneumonitis due to contamination of an air conditioner, New England Journal of Medicine (283): 271-276, 1970.

7. Fink, J.N. et al, Interstitial pneumonitis due to hypersensitivity to an organism contaminating a heating system, Annals of Internal Medicine (74): 80-3, 1971.

8. Sterling, T.D., Sterling, E., and Dimich-Ward, H., Air quality in public buildings with health-related complaints, ASHRAE Transactions, Volume 89, Part 2A&B, 1983.

9. Altshuller, A.P., Assessment of the contribution of chemical species to the eye irritation potential of photochemical smog, Journal of the Air Pollution Control Association (28): 594-598, 1978.

10. Schmidt, H.E., Hollowell, C.D., Miksch, R.R. and Newton, A.S., Trace organics in offices. Building Ventilation and Indoor Air Quality Program, Energy and Environment Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California, 1980

11. Hollowell, C.D. and Miksch, R.R., Sources and concentrations of organic compounds in indoor environments. Bulletin of the New York Academy of Medicine (57): 962, 1981.

12. Meyer, B., Indoor Air Quality, Addison-Wesley Publishing Co., Reading, Massachusetts, 1983.

13. The Steelcase National Survey of Office Environments: Do They Work? Conducted by Louis Harris & Associates Ltd., Steelcase Inc., 1980.

14. The impact of office environment on productivity and quality of working life, Buffalo Organization for Social and Technological Innovation Inc., 1981.

15. Sterling, E.M. et al, Health and Comfort in Modern Office Buildings: Results of a Work Environment Survey, Office and Professional Employees International Union, New York, N.Y., 1983.

16. Sterling, E., Sterling, T. and McIntyre, T., New health hazards in sealed buildings, American Institute of Architecture, p. 64-67, April, 1983.

17. Poulton, E.C., The environment at work, Applied Ergonomics, 3(1): 24-9, 1972, (provides a useful table analyzing 25 work conditions just severe enough to produce a reliable deterioration in performance).

18. Rotton, J., Affective and cognitive consequences of malodorous pollution, Basic and Applied Social Psychology, (in press).

19 Sterling, E., and Sterling, T., The impact of different ventilation levels and fluorescent lighting types on building illness An experimental study, Canadian Journal of Public Health, (74): 385-392, 1985.

20. Sterling, T. and Sterling, E., Building illness in the white collar workplace, International Journal of Health Services, Vol. 13(2):277-287, 1983.