The Impact of Different Ventilation Levels and Fluorescent Lighting Types on Building Illness: An Experimental Study[1]

E. STERLING, B.Arch[2], T. STERLING, Ph.D[3]

We conducted a two part experimental study to identify antecedents of complaints from office workers in a sealed, air conditioned building. We first documented building illness as increased incidence of absenteeism and complaints among office workers in the study group compared to control subjects in a non-sealed building of similar vintage.

The second part of the study monitored complaints and symptoms from subgroups when lighting was changed and when fresh air was introduced. Complaints and symptoms decreased with changes in air and lighting and increased again when previous conditions were established. This demonstrates that building illness is dependent on building design and operation.

Nous avons entrepris une étude expérimentale en deux parties pour définir les antécédents des plaintes émises par les employés de bureau travaillant dans des bâtiments dont l'air est climatisé. Nous avons tout d'abord compilé des informations concernant l'augmentation du taux d'absentéisme et des plaintes dans ce type de bâtiment par rapport à ceux d'un groupe de contrôle travaillant dans un édifice non étanche de la même époque.

La seconde partie de l'étude enregistra les plaintes et symptômes des sous-groupes après modification de l'éclairage et introduction d'air frais. Ces deux mesures entraînèrent une baisse du niveau des plaintes et des symptômes; on constata cependant une nouvelle augmentation lorsque l'on rétablit les conditions antérieures. Ceci prouve que le malaise ressenti dans les bâtiments varie selon la conception et le mode d'exploitation de ceux-ci.

The types and levels of indoor air pollutants and their effects have increasingly attracted the attention of health scientists. Public and private structures, especially modern office buildings contain a wide variety of pollutants, often exceeding levels found outdoors.[1,2,3,4]

Innovations in modes of building construction and building ventilation have profoundly affected the manner in which buildings generate, entrap or eliminate pollutants. Two of the most relevant architectural features affecting indoor pollution levels in modern buildings are the hermetically sealed air-tight shell and the mechanical heating, ventilation and air conditioning system. The quality of the ambient environment in modern office buildings depends primarily on inside activities, materials, infiltration and exfiltration characteristics and on the ventilation procedures which clean and refresh the air. The shift from natural to mechanical ventilation, variations in architectural styles, and the use of new materials, products, and equipment have changed the type of pollutants to which building inhabitants are now exposed but have not eliminated them. New materials and architectural styles have created new problems of pollutant off-gassing, dust sources, and type of viable particulates or life forms.

Recently several cases of illness have been attributed to indoor air pollutants. Legionnaire's disease has been traced to legionellosis from cooling towers and evaporation condensers.[5] Other virus-caused infections such as hypersensi-

1. This project was in part supported by the Legal Services Society of British Columbia.
2. Research Director, TD Sterling Limited, 1507 West 12th Avenue, Vancouver, B.C. V6J 2E2 (604) 733-2701.
3. Professor, Faculty of Interdisciplinary Studies, Simon Fraser University, Burnaby, B.C. V5A 1S6

tivity pneumonitis have been traced back to similar conditions.[6,7,8] Dry detergent residue left in carpets after shampooing with industrial products has been shown to cause repiratory irritation among occupants of office buildings and day care centres.[9] Outbreaks of burning eyes, coughing, breathing difficulties, nausea and dizziness among office workers have been traced back to off-gassing of formaldehyde from composition board.[10]

In many buildings, occupants have complained of general discomfort, the most frequent symptoms of which are eye irritation, headaches and fatigue. Many of these complaints have led to investigations by the National Institute for Occupational Health and Safety (NIOSH), the Center for Disease Control (CDC) and by a number of universities and other research groups.[11,12,13] These complaints have not been linked to any particular pollutant or group of pollutants. Some investigations of these buildings have concluded that the symptoms reported were of psychological origin.[14] However, it is difficult to accept this hypothesis. Without exception complaints have come from so-called energy-conserving or sealed buildings and the symptoms described have been surprisingly similar from building to building.

Although all investigations considered smoking habits, few considered tobacco smoke to be the cause of symptoms.

One hypothesis is that the non-specific symptom complex, especially 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), hydrocarbon vapors (from infiltrated auto-exhaust and off-gassing from paints and plastics), benzylic monoalcylbenzenes including toluene and styrene which combine with nitrate (with ingredients coming from glues, solvents and cleaning materials) and even trichloroethylene contained in white-out materials used by typists.[15,16,17] Moreover modern office buildings are lit by fluorescent lights, which emit variable amounts of ultraviolet radiation often around the clock.

Ultra violet emissions in the 405nm, 365nm, 297nm and 254nm wavelengths in a sample of cool white, warm white, and full spectrum fluorescent lighting were measured. Ultra violet irradiance, at the source, varied from .3mw/cm^2 to .41mw/cm^2 at 405nm, .12mw/cm^2 to .27mw/cm^2 at 365nm, .0034mw/cm^2 to .0085mw/cm^2 at 297nm, and was less than .0001 at mw/cm^2 at 254 nm. As air circulation is often directed through vents in lighting fixtures or across them on the ceiling, this type of radiation may support and enhance photochemical reactions.

It was the purpose of our study to:

1. document major health-related aspects of building illness;
2. test if performance of individuals is affected by the same conditions that may cause building illness;
3. test the hypothesis that some symptoms and complaints typical of building illness could be related to photochemical smog produced inside.

We investigated a problem building in Vancouver, B.C. in which symptoms of eye irritation, headaches, nausea and drowsiness were documented by monitoring health and comfort complaints over an extended period.

Our study began in February, 1980, at the request of the tenants, primarily clerical workers and lawyers. The tenants had recently moved from an older building with operable windows into the seventh floor of a recently remodeled, sealed mechanically ventilated office building. The investigation was divided into two parts. *Part I* documented the existence of building illness by contrasting symptoms prevalent in the study building with control conditions. *Part II* experimentally varied parameters most likely contributing to formation of photochemical smog indoors.

PART I

Part I consisted of:

1. An analysis of incidences of absenteeism among the 45 employees, both before and after the recent move. (Absentee records were provided by the employer.)
2. A comparison of answers to a complaints and symptoms questionnaire between a study and a control group.
3. A comparison of results of tests for performance including psycho-motor steadiness and visual-cognitive co-ordination between study and control groups.
4. An investigation of the ventilation and illumination characteristics of the building.

We used a self administered questionnaire to collect data on demographic characteristics, work habits and tasks, perceived environmental conditions and perceived symptoms of study and control subjects. (An expanded version of the questionnaire subsequently was used in a number of other investigations of health related building problems. Appendix A shows the questionnaire used here.) Tests for two types of performance were conducted on a random selection of subjects from the study group and control group (30 and 15 respectively). The tests included a psycho-motor steadiness (or tremor) test and a visual-cognitive co-ordination (t-crossing) test.

The tremor test involved the holding of a stylus for a constant time period as steadily as possible in varying-sized holes of a testing plate. The t-crossing test consisted of having the subject quickly read through a short paragraph and cross out all of the t's that were noticed. The tremor test has been used to measure the effects of such variables as exercise, handedness, smoking, alcohol ingestion and fatigue and to monitor performance changes in workers exposed to toxic chemicals or other stresses before overt disease symptoms are experienced.[18] The t-crossing test has been used to study the effects of exposure to pollutants on visual-cognitive performance.[19] Performance testing was conducted in both the study and control buildings over two weeks. Nine subjects were tested each day, six from the study group and three from the control group. The first run of tests was intended as a learning experience and was administered on the afternoon of the workday preceding the actual testing. The second test was conducted the morning of the following workday, and the third test that same afternoon.

Twenty tenants in a nearby building were the control group for questionnaire and performance measures. The control building was of similar vintage but still in the original condition, with operable windows for ventilation and hot water radiant heat. The control group was selected from occupants of private offices. These were secretaries and receptionists all working above the sixth floor.

The 45 subjects in the study and the 20 subjects in the control groups did not differ significantly in age, days/hours per week spent in the building, type of job, eye impairment, smoking habits, alcohol or coffee consumption. There was a difference in the female/male ratio (36 females in the study group and 11 in the control group). There was no significant difference in the mix of work stations between open areas and enclosed offices. Every member of the control group had a window view as compared to 70% of the study group.

RESULTS: PART I

The absentee data were supplied by the building tenants and span one year before and seven months after the study group moved into the study building. The percent of absent days was calculated for all staff members. In this way, the study group served as its own control, making possible the comparisons of absentee prevalence before and after the move to the new enclosed structure. Figure 1 plots the percentage of days absent per week for the study group beginning in August of 1978 and ending in February of 1980. The vertical solid line divides the graph into two parts, before and after the move.

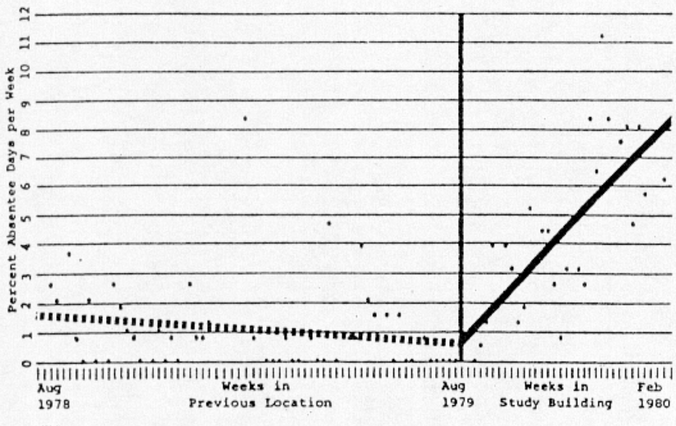

Figure 1. Absentee rate scattergram pre- and post-occupancy of study building.

There is no trend evident before the move. Most weekly absences were below 3% and there were no absences for 40% of the weeks. The dotted line is the line of best fit resulting from fitting a linear equation to the data for the period prior to the move into the study building. The slope of this line is not significantly different from zero. The coefficient of determination (r^2) between absentee rate and time is 0.03020 and the correlation coefficient (r) is -0.17377, indicating that no increasing or decreasing trend is evident.

After the move, the solid line with a positive slope of 2.66 approximates the linear trend of absentee days per week in the study building. The r^2 in this case is 0.53457 and r is 0.73155 ($p < .01$). This significant trend clearly shows that absences were on an upswing after the move, with none of the weeks showing a lack of absences and a marked high rate of absences in the winter months. No absentee records are available for periods after February, 1980. However, absentee records obtained after the conclusion of our experiments would have little bearing on these observations as ventilation rates were subsequently increased.

Figure 2 details specific complaints in a cross-group comparison. Too little air movement, too hot, too dry and too stuffy were the major complaints in the study building and were significantly more frequent than similar complaints in the control building.

Figure 3 compares complaints of symptoms of building illness. The study group reported a much higher rate of complaints of building illness than did the control. For example, the study group reported 60% more eye irritation and 20% more headaches.

The results of the performance tests are presented in Tables I and II. Table I presents the results of the tremor test. The individual scores have been aggregated into the mean morning stylus contact count and contact time, and the mean afternoon stylus contact count and contact time for each group.

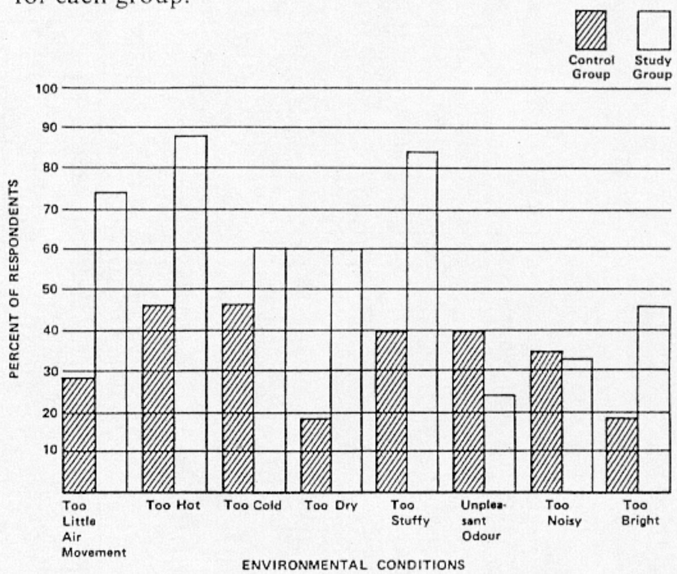

Figure 2. Work environment perception by Group.

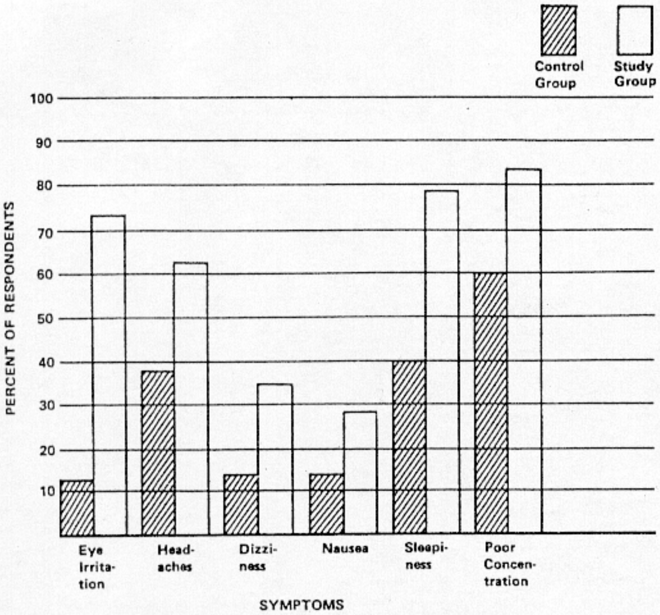

Figure 3. Symptom distribution by group.

TABLE I
Tremor Test Scores

Test Time	Count of Stylus Contacts and Total Contact Times							
	Control Group Count		Control Group Time		Study Group Count		Study Group Time	
	Mean	Stnd. Dev.	Mean	Stnd. Dev.	Mean	Stnd. Dev.	Mean	Stnd. Dev.
Morning	51.1	(21.0)	5.6	(2.9)	51.1	(29.2)	5.3	(3.3)
Afternoon	48.0	(17.9)	5.4	(2.5)	47.0	(26.6)	4.9	(3.5)
Difference	3.1		0.2		4.1		0.4	

TABLE II
T-Crossing Test Scores

Test Time	Count of T's, Number and Percent Missed					
	Control Group			Study Group		
	No. of t's	No. Missed	% Missed	No. of t's	No. Missed	% Missed
Morning	57.8	10.5	18	57.5	7.6	13
Afternoon	54.5	8.9	18	51.0	6.4	13
Difference	3.3	1.6	0	6.5	1.2	0

There was no significant difference between group scores for either count or time, nor any significant change in scores between morning and evening for either group.

Table II summarizes the results of the t-crossing test. The table is aggregated by group. The morning and afternoon mean scores for each group are presented for the number of t's encountered, the number of t's missed, and the percentage of t's missed.

The study group as a whole read slower, both in the morning and afternoon tests, but with approximately 3% greater accuracy.

In general, no significant difference in performance between groups was detected by either test. However the study group did register a slightly greater improvement in performance over a day than the control group. This is consistent with psychological literature that finds evidence for slight improvement of performance under minor conditions of stress.[20]

Ventilation and Illumination Characteristics

Ventilation to the study premises was provided solely by mechanical means. The mechanical system included a constant volume central heating, ventilation and air-conditioning (HVAC) system and five supplementary fan coil induction units located in the suspended ceiling plenum.

Conditioned air was supplied to the occupied office space through ceiling diffusers. Exhaust air was removed from the occupied office space through diffusers directly into the suspended ceiling plenum. The five supplementary fan coil units located in this plenum have no fresh air supply, therefore 100% of the air supplied to the occupied office space by these units was recirculated.

An air balance test was done to measure the volume. velocity and mixture of supply and return air delivered by the Central HVAC system. That system was capable of supplying mixtures of fresh air ranging from 25 to 87% by volume.[21] Under normal operating conditions the system supplied only 25% fresh air.

The study premises were illuminated by a combination of daylight and sunlight-simulating fluorescent lamps. Both the illumination levels and the luminous ratio were measured and found to be within ranges recommended by the Illumination Engineering Society and the British Columbia Ministry of Labour.[22,23] Product literature verified by sample tests set the ultraviolet A (UVA) emissions of the full spectrum fluorescent lamps at 35 average microwatts per 10 nanometers per lumen.[24,25] These levels are not above the NIOSH Promulgated standard for "Occupational exposure to ultraviolet radiation".[26] However, this standard is based on evidence of acute health problems, not complaints or symptoms of irritation to mucous membranes such as in the eyes.

PART II

The second part of the study was designed to test the hypothesis that two major factors accounted for the perceived environmental problems and Building Illness:

1. Excessive build-up of pollutant products indoors because of inadequate dilution of recirculated air by outside air (or by some other source of less polluted air).
2. Enhanced build-up of photochemical oxidants indoors through ultraviolet radiation emitted from sunlight simulating type of lighting impinging on pollutants.

A questionaire of perceived conditions and symptoms was given two times a week to all members of the study office for a control, a test and a final control period. Control periods preceding and following the tests were used to establish a baseline rating for environmental conditions and symptoms when normal ventilation practices were in force.

The office used in Part I was divided into two areas. Employees in these areas formed two separate experimental groups.

Group 1, consisting of 20 employees, was exposed to a change in air mixture only. For a two-week period the air that ventilated the floor area was mixed to a maximum capacity with outside air. The two-week test period was imbedded in a ten-week period in which the first six and last two weeks were monitored under normal ventilation conditions. Office personnel were not informed that a change in ventilation would occur.

Group 2, consisting of 23 employees, was exposed to changes in both air mixture and lighting. Test periods were preceded by a four-week control period and followed by a two-week control period during which normal conditions of ventilation and lighting prevailed. The initial four weeks of control period were followed by a two-week period during which lighting only was changed. The change was from sunlight simulating to standard cool white fluorescent lamps emitting approximately 5 microwatts per 10 nanometers per lumen of UVA.[24,25] During the next two-week period, full unrestricted ventilation was introduced in addition to the lighting change. For the last two weeks the sunlight simulating lamps were restored and ventilation was again reduced to its former mixture (Figure 4).

The questionnaire asked if particular environmental or symptomatic conditions existed. Answers were either "yes", or "no", or a blank. A "yes" was scored as a -1, indicative of the existence of the condition, a negative event. A "no" was scored as +1, indicating the absence of a condition, or a positive event. A blank was scored as zero or neutral. The positive and negative scores for each question were averaged for the control and for the test periods. The preceding and following control periods for each person were used to establish a base from which improvements (increase in the average positive score) or worsening (increase in the average negative score) could be evaluated. In this way health related measures had to first improve when ventilation and lighting were changed and then again worsen when original conditions were restored before indicating a change. This method of analysis was chosen to err on the conservative side as it is possible that the perception of the study itself could have influenced reaction by the subjects (i.e. the employees).

RESULTS: PART II

Table III gives the percent change (all in the direction of improvement) during the Group I test period. (Only those percent changes are given for which there was at least 5% change in average rating.)

WEEK OF STUDY	1	2	3	4	5	6	7	8	9	10
GROUP I	.	.	.	.	.	.	V	V	.	.
GROUP II	.	.	.	.	L	L	X	X	.	.

. Normal air and lighting conditions
V Ventilation only changes
L Lighting only changes
X Both ventilation and lighting changes

Figure 4. Succession of test conditions.

TABLE III

Percent changes in ratings of quality of ambient air coditions of Group 1 from Control (restricted outside air ventilation) to experimental (full outside air ventilation) phases. Positive values indicate perceived shifts to better quality.

Question	Percent Changes
Is there too much air movement?	—
Is there too little air movement?	+57.7*
Is it too cold?	—
Is it too hot?	+47.5**
Is there too much humidity?	—
Is there too little humidity?	+11.4
Is the air too stuffy?	+69.0**
Is there an unpleasant odor?	+7.6

* p of rating change by chance < .05
** p of differences by chance <.01
— change sless than 5%

TABLE IV

Percent changes in ratings of quality of lighting conditions by Group 2 when lighting was changed and when air quality was changed. Positive changes indicate perceived shift to better quality.

Question	Percent change for Light (but not air change	Percent change for Light and Air Change)
Is the lighting too bright?	+19.2	+26.7
Is the lighting too dark?	—	—
Is there too much glare?	+22.8	+28.3

TABLE V

Percent decrease in symptoms during periods of full ventilation, light change, and light change plus full ventilation.

Symptoms	Group I Full Ventilation	Group II Light Change	Light Change and Full Ventilation
Eye Irritation	6.8	8.0	31.2*
Headaches	—	—	19.3
Dizziness	—	—	—
Nausea	—	—	5.7
Sleepiness	17.4	9.4	10.7
Irritability	—	10.4	11.6
Change of Mood	—	9.3	11.6
Reduced Concentration	14.8	10.3	11.5
Depression	—	—	—
Elation	—	—	—

— less than 5% change
*p of change, change < .01

Dramatic changes were perceived in air movement, heat and stuffiness. These perceptions are not unrelated to each other. A decrease in stuffiness is very likely a summary of the feeling that there is more air movement and less heat. However, it should be kept in mind that in a constant volume ventilation system of this type it *is not physically possible for air movement to actually change.* The only controlled change was in the content and mixture of the air which now contained more outside air. The slight improvement in perception of odor was to be expected. However, that increase was not statistically significant.

Table IV summarizes the changes in rating of lighting quality. (As there were no changes in the perceived light quality for Group I which had no lights changed, that group is not included in Table IV.) Lighting was felt not to be too bright and, at the same time, adequate. (That is, not too dark.) Perception of glare improved. It is interesting, however, that there was a significant change in the perception of light quality when both light and air changes occurred than when only lights were changed. Differences were tested by analysis of variance and were found to be statistically significant ($p < .05$).

Table V summarizes changes in reported symptoms. Again, changes of less than 5% are now shown.

Changes in lighting or changes in ventilation seem to have had the same effect. With one exception none of the changes were statistically significant. The consistent improvement is an indication that changes were not chance events.

There was a dramatic and statistically significant decrease in eye irritation when the lighting change was accompanied by changes in ventilation. This finding supports our hypothesis that eye irritability in many offices may be due to the build-up of photochemical byproducts and this build-up is accelerated when light contains ultraviolet emissions. While presence of photochemical smog is difficult to test directly, we feel that the hypothesis is convincing and reasonably supported by our test results.

DISCUSSION

Our observation of increased absenteeism corresponds to reports from other building illness studies. While these reports are mostly anecdotal there is general agreement that absenteeism is a measure of health effect of indoor pollutants. Of course, in some instances other factors such as job satisfaction and alcoholism or epidemics (such as influenza) may be responsible. There is no evidence that any of these extraneous factors could have influenced results in this instance.

Cigarette smoking has been cited as a major cause of indoor air pollution.[27,28,29] Therefore considerable attention needs to be paid to possible confounding because of differences in smoking related substances between the groups that were compared.

In the first study, the groups compared were in two different buildings. The study building depended on a recirculating mechanical system for air supply. Any contaminant generated anywhere within the building such as cigarette smoke (but also formaldehyde, or photo copier fumes) would add to pollution levels within the whole building. The control building, with only window ventilation, would not tend to distribute contaminants from one separate office to another. However, most of these contaminants were individually reproduced in each of these offices because of use of photo copiers or presence of smokers so that the same background pollution sources were present in both buildings.

The second study divided the office population in the study building (of the first study) into two groups. Response changes of these two groups were compared. Both groups were serviced by the same mechanical ventilation system. In fact they were on the same floor. Thus both groups were exposed to the same background contamination. Questions on complaints about odor were asked but no difference noted.

Relative humidity measured in both buildings over the first study period was within acceptable standards. There is a possibility of a difference in dust levels and types between the two buildings. In general, with the possible exception of dust from outdoors, there were no significant differences in the background sources of pollutants including cigarette smoke among the compared groups in the first and second studies.

The comparison of complaints between workers in a sealed building with workers who had the option to open windows has since been verified in another study in which we have shown that complaints about environmental conditions as well as reported symptoms vary directly with access to operable windows.[13]

While we were not able to measure levels of various chemicals that caused photochemical smog, we were able to show that the frequency with which eye irritation was reported, which is one indication of the presence of photochemical smog, subsided when ventilation was increased and sunlight simulating fluorescent lamps were replaced by lamps emitting less ultraviolet. While our experiment does not prove that photochemicals were present, the hypothesis is supported by the rapid decline in reported eye irritation when conditions enhancing the formation of photochemical smog were changed and by the recurrence of the symptom at previous levels after old conditions had been re-established. Chemical antecedents of photochemical smog (formaldehyde, aldehydes, hydrocarbon vapors, benzylic monoalcylbenzenes, trichloroethylene and possibly also peroxyacetyl nitrates) are known to be present in an office indoor atmosphere. One source of the problem in sealed office buildings leading to symptoms of non-specific building illness very likely might be photochemical smog formed by the interaction between pollutants infiltrating the building or being generated within the building and by catalytic actions by ultraviolet-radiating fluorescent lighting.

Work Environment Survey

1. Name ______________________ 2. Age ____ 3. Sex: M [ ] F [ ]

4. Is your eyesight impaired? yes [ ] no [ ] don't know [ ]

5. If yes, do you wear glasses [ ]; contact lenses [ ]; neither [ ]

6. Is your hearing impaired? yes [ ] no [ ] don't know [ ]

7. If yes, do you wear a hearing aid? yes [ ] no [ ]

8. Approximately how many cigarettes, cigars, or pipes do you smoke each day? ______

9. Do you usually eat breakfast? yes [ ] no [ ] sometimes [ ]

10. Do you usually eat lunch? yes [ ] no [ ] sometimes [ ]

11. Are you aware of any problems with your health? yes [ ] no [ ]

12. If yes, please specify. ______________________

13. Do you take medication (such as aspirins, cold remedies, antihistamines, prescribed drugs) regularly? yes [ ] no [ ]

14. If yes, is any of your regular medication prescribed by a physician? yes [ ] no [ ]

15. Please indicate your job title or definition. ______________________

16. List examples of tasks you typically perform (such as filing, typing, writing). ______________________

17. How long have you been working at this job? _____ years _____ months

18. Does your job require that you leave the office during the working day?
regularly [ ] sometimes [ ] never [ ]

19. Approximately how many hours do you work per week? _____ hours

20. Approximately how many hours do you work per day? _____ hours

21. Is your main workstation in an open office area [ ] enclosed office [ ]
other [ ], please specify ______________

22. Do you have a secondary workstation in an open office area [ ] enclosed office [ ]
other [ ], please specify ______________

23. Approximately how many hours a day do you spend at your main workstation? _____ hours

24. Can you see a window from your main workstation? yes [ ] no [ ]

25. Do you use a typewriter? regularly [ ] sometimes [ ] never [ ]

Page 1 of 4

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26. Do you use a video display unit? regularly [ ] sometimes [ ] never [ ]

27. Do you use a duplicating machine? regularly [ ] sometimes [ ] never [ ]

Indicate whether you frequently experience any of the following environmental conditions at your workstation. If your answer is yes, check the column indicating when these conditions usually occur.

	ENVIRONMENTAL CONDITIONS	NO	YES				COMMENTS
			A.M.	P.M.	All Day	Varies	
28.	Is there too much air movement?						
29.	Is there too little air movement?						
30.	Is the temperature too hot?						
31.	Is the temperature too cold?						
32.	Is there too much humidity?						
33.	Is there too little humidity?						
34.	Does the air ever feel stuffy?						
35.	Does the air ever have an unpleasant odor?						
36.	Is the noise level too high?						
37.	Is the lighting too bright?						
38.	Is the lighting too dark?						

39. If there are other environmental conditions that bother you that are not indicated, please specify. ______________________

Page 2 of 4

TDS LIMITED

40. Have you noticed any improvement in the environmental conditions at your workstation in the past month? yes [ ] no [ ] don't know [ ]

41. If yes, please specify. ______________________

Indicate whether you frequently experience any of the following symptoms at work. If your answer is yes, check the column indicating when these symptoms usually occur.

	SYMPTOMS	NO	YES				COMMENTS
			A.M.	P.M.	All Day	Varies	
42.	Eye irritation						
43.	Headaches						
44.	Dizziness						
45.	Nausea						
46.	Sleepiness						
47.	Irritability						
48.	Change of mood						
49.	Reduced concentration capacity						
50.	Depression						
51.	Elation						

52. Please specify any symptoms that have not been included. ______________________

Page 3 of 4

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The following questions refer to corrective measures taken to compensate for uncomfortable environmental conditions at work.

53. Do you have to put on extra clothing for comfort at your workstation?
regularly [ ] sometimes [ ] never [ ]

54. Do you have to remove some clothing for comfort at your workstation?
regularly [ ] sometimes [ ] never [ ]

55. Do you leave the building during lunch break or any other time during the work day?
regularly [ ] sometimes [ ] never [ ]

56. Do you use a fan at your workstation?
regularly [ ] sometimes [ ] never [ ]

57. Do you use an electric heater at your workstation?
regularly [ ] sometimes [ ] never [ ]

58. Do you use any corrective measures that have not been included? Please specify.
____

THANK YOU FOR YOUR ASSISTANCE. WE WOULD LIKE TO ASSURE YOU THAT ALL INFORMATION WILL REMAIN CONFIDENTIAL.

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To what extent such likely photochemical reactions contribute toxic irritants needs to be established. On one hand, photon path length is quite short, affecting a small volume of air around a fluorescent fixture. On the other hand, many ventilation systems circulate air around or even through vents built into the fixtures, thus exposing a very large volume of air to photon bombardment. We are investigating the problem by measurements of chemical components.

In many ways the modern airtight shell enclosed space resembles a submarine in that its indoor atmosphere has to be kept fit for human lungs. Problems of submarines and modern buildings differ in specific instances but are similar in kind.[2,30,31] For example, phosgene has been created in a submarine by leaked Freon 11 interacting with other air components in air incineration processes designed to recover oxygen. In parallel we find that in some types of buildings chemical processes appear to be accelerated and catalyzed by ultraviolet emissions from modern fluorescent lamps, especially those designed to simulate outside light.

However, the difficulty often lies not so much with specific sources that emit and/or trap pollutants indoors but with the adequacy of ventilation procedures.

Buildings must serve human needs which include such diverse actions as photocopying, coffee making, smoking, plant growing, bringing dust into inside premises, and so on. Appropriate mechanical, heating, ventilation, air conditioning and lighting systems are required if modern hermetically sealed buildings are to serve human needs adequately. With the increasing cost of energy, providing these mechanical services has turned out to be expensive. Experience has shown that reductions in mechanical systems such as ventilation and lighting to save energy often conflict with human health and safety requirements. Unless existing buildings are operated as originally designed regardless of the energy expense, the health expenses to people working in these buildings may be great in the long run.

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