Epidemiology of sick building syndrome and its associated risk factors in Singapore

P L Ooi, K T Goh, M H Phoon, S C Foo, H M Yap

Abstract

***Objectives*—To investigate the occurrence of sick building syndrome in a tropical city, and its relation to indoor air quality and other factors.**

***Methods*—2856 office workers in 56 randomly selected public and private sector buildings were surveyed. The study consisted of a self administered questionnaire assessing symptoms and perception of the physical and psychosocial environment, inspection of the building plans and premises, and measurement of temperature, relative humidity, respirable particles, chemicals, bioaerosols, and other variables.**

***Results*—Symptoms typical of the sick building syndrome were reported in 19.6% of the respondents. Multivariate modelling substantiated contributions associated with low thermal comfort, high work related stress, too much noise, a history of allergy or other medical conditions, poor lighting, young employees, and female sex. Measurements of indoor air quality or ventilation were not found to be reliable predictors of the symptoms.**

***Conclusion*—The survey confirmed the presence of sick building syndrome and its risk factors in the tropics. A biopsychosocial approach to the problem involving symptomatic treatment, environmental control, good ergonomic design, and stress management is recommended.**

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Keywords: sick building syndrome; environmental epidemiology; tropical city

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The island city state of Singapore is notable for its many modern high rise office buildings with air conditioning throughout the year. Its tropical climate, densely built environment, and energy conservation requirements pose special constraints to the building industry in ensuring that ventilation and indoor air quality within the fully enclosed offices remain acceptable. In tandem with rapid urbanisation as a newly industrialised economy, the prevention of ill health in the office presents a growing challenge to medical practitioners and building managers. The past decade has seen increased awareness of health hazards which could arise, accumulate, or disseminate as a result of the mechanical ventilation systems.[1–4] In 1985, the Ministry of the Environment initiated a surveillance programme on legionnaires' disease and the distribution of the causative bacteria in the cooling towers.[5 6] This was followed in 1992 by the publication of a code of practice for use by building owners and management corporations in the servicing and maintenance of air conditioning cooling towers.[7] Other illnesses associated with buildings continue to be investigated.[8 9] Although the cause of most building related symptoms remained unknown, the increasing reliance on artificial ventilation has fueled a widespread perception of indoor air pollution as the problem.[10 11]

The sick building syndrome is a major concern because of the many people potentially at risk. It was defined by the World Health Organisation (WHO) as an excess of work related irritations of the skin and mucous membranes and other symptoms, including headache, fatigue, and difficulty concentrating, reported by workers in modern office buildings.[12] The condition had been well documented in the temperate countries where it was considered a major cause of sickness absenteeism and lost productivity among the workers.[13 14] As baseline data in the tropics were lacking, we conducted a nationwide morbidity survey involving 2856 office workers in 56 randomly selected public and private sector buildings. The objective was to investigate the occurrence of sick building syndrome and its relation to indoor air quality and other factors.

Methods

Our multidisciplinary team included two medical epidemiologists, an industrial hygienist, an engineer, a chemist, a microbiologist, two research assistants, and two health officers. In 1992–5, the stages of work involved survey design, administration of a standardised questionnaire assessing symptoms and perception of the physical and psychosocial environment, walk through inspections of the buildings, measurements of the indoor climate, and statistical analyses of the data.

The subjects in the study were recruited from a source population of all public and private buildings inside and outside Central Business District, the commercial and financial hub of Singapore. We used a randomised multistage cluster sampling procedure. Figure 1 shows the details of the procedure and results, including restrictions and losses of premises and people. The 56 building owners and 127 office managers or employers were approached individually to obtain consent for inclusion of their premises as part of the survey. The participation rate for the selected buildings was 100%, but that for offices was 99.2% (one private sector office which had agreed to cooperate

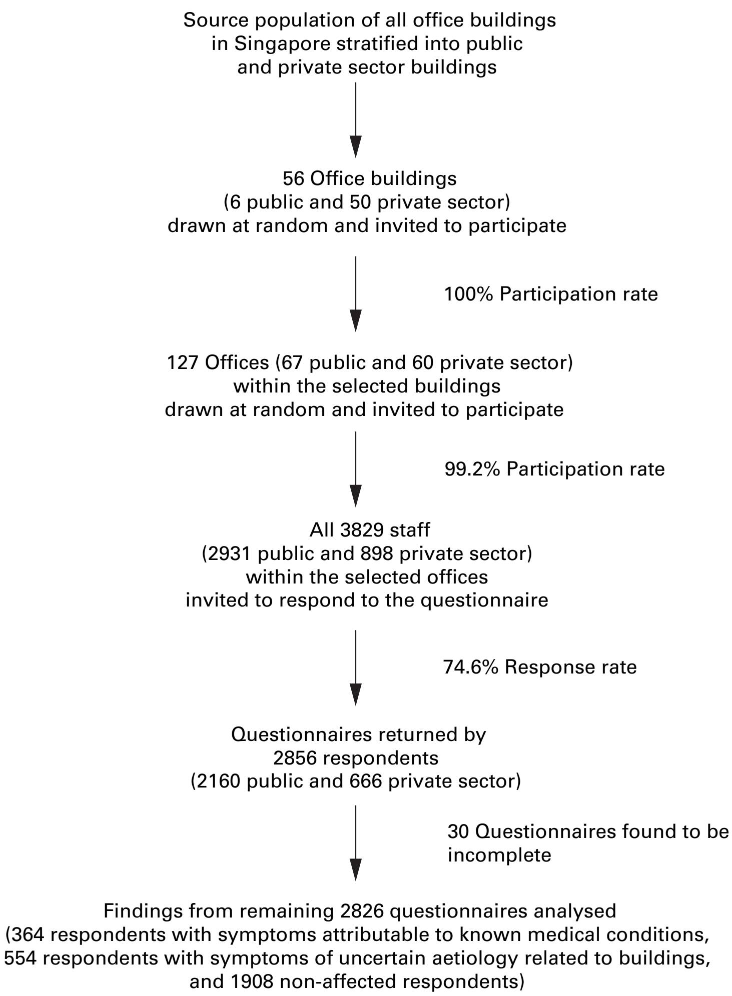

Figure 1 Randomised multistage cluster sampling procedure showing restrictions and losses of premises and people.

withdrew from the study). These premises had no known building related problems at the time of the survey. The numbers of staff in the selected offices ranged from two to 93, with a mean of 30.

Between July 1992 and December 1994, 3829 confidential questionnaires were distributed individually after explanation and collected immediately on completion. We structured the self administered questionnaire in English, the language universally spoken and understood in Singapore offices. The data included sex, age, race, medical history, nature of work, and personal experience of work related stress. Subjects were asked to evaluate their thermal comfort, and noise and lighting quality at the workplace. Other details related to environmental exposure included the characteristics of their workstation and time spent there, work with or near specific office equipment, and perceptions of odour or stuffiness. Subjects were also asked if they had over the past four weeks had the following problems: fatigue, headache, drowsiness, dizziness, shortness of breath, nausea or vomiting, skin dryness or rash, and eye, nose, or throat irritation. In assessment of the sick building syndrome, we excluded subjects with pre-existing medical conditions which could account for their symptoms—for example, current respiratory infection, pregnancy—but not those with known illness that were free from acute exacerbations at the time of the survey. We used criteria compatible with the WHO definition for a case of sick building syndrome (onset of two or more symptoms at least twice weekly while in the building), overnight resolution of these symptoms after leaving the building or workstation, and absence of known medical causes.

Supplementary data were obtained by walk through inspections of the buildings and monitoring of indoor air quality. Although we attempted to reduce any delay between the administration of the questionnaires and these activities as much as possible, a time lag of one to three weeks was usually noted because of logistic and administrative issues. With a building checklist and floor plans, we carried out detailed inspection of the offices, ventilation systems, and other facilities. The offices were typically equipped with central air conditioning, fluorescent lighting, and wall to wall carpeting and comprised open concept workstations for junior staff and a few enclosed rooms for senior staff. We confirmed that smoking was prohibited in all the premises, and no renovation work was in progress. Table 1 shows the indoor variables investigated, types of analytical instruments used, and their detection limits. Indoor air samples were collected from the breathing zone, about 1.4 m above the floor, at over 285 locations within the premises based on approved methods.[15–17] Reference outdoor samples were taken from fresh air intake points located in the air handling rooms of the buildings.

For the statistical analyses, unmatched controls were drawn from the non-affected respondents at over three times the number of cases to ensure adequate statistical power. Differences in the distribution of risk factors between cases and controls were firstly compared by the χ^2 test, and odds ratios with 95% confidence intervals derived.[18] In our exploratory data analysis, we also divided the symptoms into subgroups to assess their correlation with specific risk factors. The contaminant concentrations of the offices, and between the indoor and outdoor air, were compared by the non-parametric Mann Whitney *U* test. Significant variables were then subjected to multiple logistic regression modelling to simultaneously adjust for potentially confounding covariates.[19] Stepwise selection was used to eventually develop a final model that might explain the occurrence of symptoms in our study population. The fit of this model was next assessed by the log likelihood and Hosemer and Lemeshow tests. All computations were performed with Epi Info (Centers for Disease Control and Prevention, Georgia), SPSS (SPSS , Illinois) and SAS (SAS Institute, North Carolina) software.

Results

The final sample consisted of 2856 workers (74.6% response) drawn from 126 offices within 56 buildings located throughout the island (fig 1). As 30 of the questionnaires were returned incomplete, this paper is based on the remaining 2826 respondents. The respondents comprised 2160 (76.4%) public and 666 (23.6%) private sector employees, with ages ranging from 16 to ⩾60. Women outnumbered men by a ratio of 3:2. The racial composition, comprising 79% Chinese, 12% Malays, 7% Indians, and 2% others, closely mirrored that of the Singapore population.

After excluding 364 (12.9%) respondents with health complaints attributable to known medical conditions, 554 (19.6%) reported frequent building related symptoms of uncertain aetiology. Figure 2 shows a frequency distribution of the proportion of affected workers within the different buildings. The symptoms were fatigue (12.3%), dry throat (10.9%), eye irritation (9.1%), stuffy nose (8.7%), drowsiness (8.3%), headache (7.1%), skin dryness or rash (4.8%), dizziness (2.8%), shortness of breath (2.3%), and nausea or vomiting (0.5%). A quarter (25.5%) of these cases thought that their symptoms occurred more in the afternoon whereas most did not notice a trend in time. These symptoms were generally not severe; the cases recorded a mean of 0.6 days (range 0–10 days) medical leave over a four week period compared with 0.2 days (range 0–7 days) for other occupants. This difference was not significant.

Table 2 shows the prevalence of personal and perceived environmental factors in relation to the building related symptoms. The multiple associations were consistent when we analysed subsamples of public and private sector office workers and varied the case definition from two or more symptoms to at least one symptom. Most of these factors remained significant independent determinants of the risks of building related symptoms even after adjustment for confounding (table 3). The multiple logistic regression modelling substantiated contributions associated with low thermal comfort, high work related stress, too much noise, a history of allergy or other medical conditions, poor lighting, young employees, and female sex. No collinearity in the independent variables was found. Criteria for assessing our final model suggested that the fit was satisfactory (p<0.001).

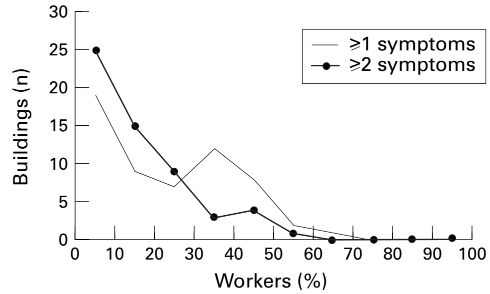

Figure 2 Frequency distribution of the proportion of workers reporting symptoms related to buildings from 56 office buildings in Singapore.

We did not find measurements of indoor air quality or ventilation to be reliable predictors of the symptoms. The indoor variables monitored in the vicinity of most complainants remained largely within acceptable limits (table 4). The commonest air pollutants detected during the workshift were formaldehyde emissions from new furnishings containing formaldehyde based resins, and carbon dioxide from human respiration. Up to 15% of the offices showed inadequate ventilation contributing to build ups in excess of 120 μg/m^3 and 1000 ppm, respectively. Although low thermal comfort had been implicated in the questionnaire survey, we noted no obvious relation of symptoms with fluctuations of temperature, relative humidity, and air movement beyond recommended levels.[20] The correlation between symptom subgroups and measured exposures was also poor. Walk through inspections showed that the buildings were satisfactorily maintained with no major irregularities that

Table 1 Indoor variables investigated, analytical methods used, and their detection limits

Variable	*Methods*	*Instruments*	*Detection limit*
Carbon dioxide	Non-dispersive infrared spectroscopy	GFC model 41/41H carbon dioxide analyser, Metrosonic aq502 indoor environment monitor	0.01 ppm
Carbon monoxide	Non-dispersive infrared spectroscopy, voltage toxic electrochemical sensor	GFC model 48 carbon monoxide analyser, Metrosonic aq502 indoor environment monitor	0.1 ppm
Ozone	Ultraviolet photometry	Thermo environmental model 49 ambient ozone analyser	0.01 ppm
Volatile organic compounds	Thermal desorption with gas chromatography-mass spectrometry, photoionisation at 10.6 eV	OI-Analytical 4460A, HP 5890 gas chromatograph, HP 5988 mass spectrometer, Photovac Microtip MP1000 photoionisation detector	0.01 ppm
Formaldehyde	Solid adsorbent sampling with high performance liquid chromatography	DNPH Sep-Pak cartridges, Shimadzu HPLC (UV-vis detector), HP1090 liquid chromatograph	0.5 μg/m^3
Respirable particles	Continous mass monitoring, piezoelectric microbalance	Model PC2 aerosol particle analyser, Kanomax Model 3511 respirable aerosol mass monitor	0.01 μg/m^3
Heat stress	Black globe and natural dry bulb sensor	Metrosonic hs360 heat stress monitor	0.1°C
Air temperature	Resistance thermal detector	Metrosonic aq502 indoor environment monitor	0.1°C
Relative humidity	Capacitance sensor	Metrosonic aq502 indoor environment monitor	0.1%
Air movement	Hot wire anemometry	Kanomax model 24-6111 anemometer	0.01 m/s
Noise	Equivalent continuous sound level (L_{eq}), A weighted	Bruel and Kjaer 4436 noise dose meter	0.1 dBA
Lighting	Photocell	Metrosonic aq502 indoor environment monitor	1 lux
Total bacterial counts	Tryptic soy agar culture	Andersen N6 single stage impactor	1 CFU/m^3
Total fungal counts	Potato dextrose/rose bengal streptomycin agar culture	Andersen N6 single stage impactor	1 CFU/m^3

Table 2 Univariate analysis of prevalence of personal and environmental risk factors for symptoms related to buildings

Study variable	*Cases (n=554)*	*Controls (n=1908)*	*OR (95% CI)**
Sex:			
Female	371	1054	1.64 (1.34 to 2.01)
Age (y):†			
16–25	136	306	1.70 (1.34 to 2.15)
26–35	195	572	1.27 (1.03 to 1.56)
36–45	114	540	0.66 (0.52 to 0.83)
> 45	30	237	0.40 (0.27 to 0.61)
Race:			
Chinese	435	1521	0.93 (0.73 to 1.18)
Malay	65	205	1.10 (0.81 to 1.50)
Indian	36	116	1.07 (0.71 to 1.61)
History of a medical condition:			
Sinus problems	115	187	2.41 (1.85 to 3.14)
Migraine	118	201	2.30 (1.78 to 2.98)
Allergies (including asthma)	82	134	2.30 (1.70 to 3.11)
Job grade:			
Senior staff (managerial, professional)	191	664	0.99 (0.80 to 1.21)
Secretarial	25	76	1.14 (0.70 to 1.85)
Clerical	194	674	0.99 (0.81 to 1.21)
Other (technical, uniformed)	144	494	1.01 (0.81 to 1.25)
Work related experiences:			
Long hours daily (>8 h)	98	243	1.47 (1.13 to 1.92)
High stress level at work	294	555	2.75 (2.26 to 3.36)
Thermal comfort at workstation:			
Extreme cold requiring extra clothing for comfort	161	327	1.98 (1.58 to 2.48)
Insufficient air movement	267	443	3.08 (2.51 to 3.77)
Stuffiness	119	112	4.39 (3.29 to 5.85)
Other environmental exposures:			
Too much noise	173	316	2.29 (1.83 to 2.86)
Poor lighting	88	141	2.37 (1.76 to 3.18)
Use of visual display unit	307	876	1.46 (1.21 to 1.78)
Type of office building:			
Public sector	437	1485	1.06 (0.84 to 1.35)
Private sector	117	423	0.94 (0.74 to 1.19)

* In the interpretation of ORs, the value for each specific category—for example 1.7 for age-group 16–25 years—is obtained in comparison with all other categories (all other age groups).
† This variable was missing for 79 cases and 253 controls.

could affect air quality by releasing pollutants or reducing ventilation. The detailed methodology and results of these investigations will be published elsewhere.

Table 3 Multivariate analysis (logistic regression model) of significant determinants predicting the sick building syndrome

Significant determinant	*Adjusted OR (95% CI)**	*p Value*
Low thermal comfort at workstation	2.84 (2.31 to 3.51)	0.0001
High stress level at work	2.41 (1.96 to 2.96)	0.0001
Too much noise	2.06 (1.63 to 2.61)	0.0001
History of a medical condition	1.89 (1.51 to 2.35)	0.0001
Poor lighting	1.83 (1.34 to 2.49)	0.0001
Young employee (16–25 y)	1.57 (1.22 to 2.03)	0.0001
Female	1.31 (1.05 to 1.63)	0.0161

*Adjusted for mutual confounding between significant independent variables (thermal comfort, stress experience, noise, medical condition, lighting, 16–25 year age-group, and sex).

Table 4 Summary of analytical results for selected indoor variables monitored within 56 air conditioned office buildings in Singapore

Variable	*Sampling time*	*Locations (n)*	*Mean value*	*Lower limit*	*Upper limit*
Carbon dioxide (ppm)	6–8 h	228	808	350	1560
Carbon monoxide (ppm)	6–8 h	228	1	0.1	5
Ozone (ppm)	6–8 h	48	0.05	0.01	0.47
Volatile organic compounds (ppm)	6–8 h	79	1.9	0.03	37.8
Formaldehyde (μg/m³)	6–8 h	266	34	2	271
Respirable particles (μg/m³)	6–8 h	180	23	0.2	120
Heat stress (°C)	6–8 h	180	0.4	0.1	0.6
Air temperature (°C)	6–8 h	285	23	19	27
Relative humidity (%)	6–8 h	285	64	41	89
Air movement (m/s)	6–8 h	180	0.1	0.05	0.83
Noise (dBA)	6–8 h	180	59	56	62
Lighting (lux)	6–8 h	228	513	197	822
Total bacterial counts (CFU/m³)	4 min	76	204	19	1360
Total fungal counts (CFU/m³)	4 min	76	63	5	1062

Discussion

Singapore has well established outdoor air quality standards,[21] but they have had little impact on indoor air quality. This is because the types and sources of pollutants found indoors remain quite different from those outdoors. The need to minimise the risk of health effects arising from poor indoor air quality is made more acute by the fact that people spend much more time indoors than outdoors. To improve the indoor air quality within office premises, the Ministry of the Environment has published guidelines on conducting periodic building inspections, obtaining feedback from the occupants, and monitoring indoor air variables.[22] These guidelines were based on our three year study and it was intended that building owners periodically gauge their indoor air quality and if necessary, upgrade their maintenance or undertake further remedial action.

We found that at any one time, at least one in five workers could be expected to have health complaints which were attributed to the building. The ailments included general or neurotoxic reactions (fatigue, headache, drowsiness, dizziness), eye irritation, irritation of the nose, throat, and airway (stuffy nose, dry throat, shortness of breath), skin irritation (dryness, rash), and other complaints (nausea, vomiting). These building related symptoms were non-specific and had many possible causes.[13] None the less, a consistent temporal relation could be established with symptoms which increased or became more apparent over the workshift and which resolved upon leaving the premises. This feature resembled symptoms reported in the sick building syndrome of temperate countries. As there is no definitive diagnosis for the condition—for example, by immunological or biochemical tests—we found that the prevalence of the syndrome among office workers could vary with the specificity of criteria used to define a case, and with the degree of investigation to exclude other causes. This was demonstrable by a shift in the frequency distribution of the proportion of affected workers within the different buildings when we changed the criteria from two or more symptoms to at least one symptom. Hence, empirical definitions of the syndrome based on a proportion—for example, in excess of 20%–30% of workers in the building being affected—were not too helpful.

The consistent temporal relation between the symptoms and the air conditioned office premises substantiated the important role of the physical environment in the aetiology of ailments. However, it was uncertain whether the pollutants detected had contributed to the symptoms because the only significant relations between sick building syndrome and environmental factors were found for perceived indoor air exposure reported in the questionnaire, and not objective measurements of these factors in the office. Unlike industrial settings where evaluation can be directed by chemical analysis of the materials used by or in the vicinity of the affected workers, it would be extremely difficult and costly to characterise all exposures and their health effects within the office environment.

The exact mechanisms triggering the health complaints are still not fully understood, but one important determinant seemed related to the perception of low environmental comfort among the occupants. These thermal comfort, lighting, and acoustic problems pointed to an urgent need for more ergonomically sound designs of the workplace. A lack of control over the thermal climate, for example, may not in itself be as serious as air pollution, but could cause significant distress and affect an occupant's perception of the workplace, particularly if the temperature and humidity often fluctuated as adjustments were attempted.[8] Similarly, problems related to inappropriate lighting have been implicated in studies of the sick building syndrome.[23 24]

Certain limitations in our study might have contributed to the lack of correlation between sick building syndrome and measured exposures. Firstly, because of a one to three week time lag between the administration of questionnaires and the indoor air measurements, we could not exclude the possibility that a causative agent for symptoms that were reported in the questionnaire may have been ventilated out of the building before indoor air sampling began. Secondly, we relied exclusively on self reported symptoms and did not include examination by a physician to verify the actual extent of illness among those exposed. In the absence of clinical consensus on what constituted sick building syndrome, our case definition could have inadvertently excluded some sensitive subjects. Finally, as with any retrospective survey, bias might lie in the selective recall of details by cases. Those affected usually search their memories for an exposure in an attempt to explain or understand why they acquired the illness, which would cause more of an association to be found between symptoms and perceived exposures than measured exposures.

It is likely that the larger number of cases identified among young employees was the result of an environmental adaptation and self selection process operating in the older employees who had worked longer. Over time, as workers who were unable to adapt continued to leave employment because of ill health or other complaints, a healthy worker effect probably emerged among those who stayed behind. The potential presence of these other risk factors suggested that, besides expending scientific effort on environmental measurement, we should continue to identify markers of individual susceptibility.[25–27]

The inability of indoor air quality measurements to reliably predict the sick building syndrome indicated some influence exerted by personal and psychosocial variables on the person's health status and health seeking behaviour. A predisposing factor among cases seemed to be concurrent medical conditions which increased their sensitivity. The reasons were not fully clear, whether physiological or otherwise, but the probability that these conditions created a heightened individual awareness of building related symptoms could be relevant to the observation. In this respect, we also think that women are marginally more attuned than men, which could account for some of the excess in symptom prevalence reported among women in our study.

The affected workers were noted to self report high levels of social and organisational stress. Studies have shown that many factors in the workplace can be stressful emotionally and physically.[28 29] Job role ambiguity, unreasonable deadlines, and interpersonal conflicts form just three of the many scenarios that might create various stressors, causing discontent at work. Even the same stressor could elicit very different reactions in different people. Although a high level of stress would motivate some to work harder, it might also provoke psychosomatic responses and make those with lowered thresholds of tolerance assume a sick role. As psychosocial ailments could occur irrespective of any real building problems, it is likely that for some people, improving ventilation or indoor air quality would not significantly ameliorate their symptoms.

Our survey confirmed the occurrence of sick building syndrome and its risk factors in the tropics.[30] It also identified the need for further studies of building associated illness in the tropics. We think that the office workers who reported symptoms were expressing susceptibility to a total environmental burden consisting of the many factors acting independently. We therefore recommend a biopsychosocial approach to the problem involving symptomatic treatment, environmental control, good ergonomic design, and stress management.

Physicians should consider these possibilities in their patients who regularly seek treatment for non-specific building related symptoms.[8]

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Appendix: Survey questions on symptoms related to sick building syndrome among office occupants

Please indicate your experience of the following symptoms at work during the past four weeks:

Fatigue—Daily / 2–3 times weekly / Less
Headache—Daily / 2–3 times weekly / Less
Drowsiness—Daily / 2–3 times weekly / Less
Dizziness—Daily / 2–3 times weekly / Less
Shortness of breath—Daily / 2–3 times weekly / Less
Nausea/vomiting—Daily / 2–3 times weekly / Less
Stuffy nose—Daily / 2–3 times weekly / Less
Dry throat—Daily / 2–3 times weekly / Less
Skin dryness/rash—Daily / 2–3 times weekly / Less
Eye irritation—Daily / 2–3 times weekly / Less

Please state the number of days in the past four weeks that you had to take off work because of these complaints:

When do these complaints occur?

Mornings / Afternoons / No noticeable trend

When do you experience relief from these complaints?

After I leave my workstation / After I leave the building / Never

Please indicate if you have any of these medical conditions:

Asthma? - Yes, on medication / Yes, not on medication / No

Allergy? - Yes, on medication / Yes, not on medication / No

Sinus? - Yes, on medication / Yes, not on medication / No

Migraine? - Yes, on medication / Yes, not on medication / No

Other? (please specify)- Yes, on medication / Yes, not on medication / No

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