There is a third reason. Science and technology are respected throughout the world, and enjoy an acknowledged authority. But where is the authority of science? It does not reside in a government, or a minister, or a university president, or in the director of a national laboratory. The authority of science resides in the collective professional conscience of the international scientific community. It is exercised through peer judgements, through journal editorial boards, through grants screening committees--and at national and international meetings such as this one. Here the scientists and engineers come to present their data, describe their technology, and explain their theories and ideas. Here they listen to criticism, to objections, to comments and to refutations. And out of the debate and discussion and arguments there gradually emerges a consensus. This consensus is the authority of science.

And so for three days, you, the delegates of this meeting constitute and exercise the authority of science in your specialized area. It is a heavy burden of responsibility, which we thank you for accepting. It makes you triply welcome.

BUILDING ILLNESS IN A LARGE OFFICE COMPLEX

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Epidemiological studies were made in 1983-84 in a large sealed office complex in which health complaints had been made since first occupation in 1977. The investigation comprised: a questionnaire survey of a stratified random sample of 1370 current employees, a telephone inquiry from a selected sample of 281 past employees, and a limited environmental survey on 9 selected floors and at 32 individual work locations. A response was obtained from 94% of the available current and 75% of the past employees. Most respondents had suffered from upper respiratory tract and eye irritation, a variety of other complaints - typically headache, drowsiness, exhaustion, sleeplessness and irritability - and some skin dryness and irritation. The symptoms usually started shortly after first employment, were troublesome at work but not at home and tended to persist at other work locations. About a quarter of those affected stated that they had been absent from work as a result and most had sought medical advice. Age, sex, type of work, year first employed and work location had little effect but there was a tendency for those who worked in cubicles to have suffered more than those in open areas or closed offices. The environmental tests indicated that some locations had less than optimal ventilation, temperature and humidity but these assessments correlated poorly with symptom prevalence. However, few locations were tested, and only during a 3-month period in 1983-84, whereas the complaints had begun years earlier. Considerable attention was given to the outcome of pregnancy in women who conceived while employed at the complex. Of 222 such pregnancies, the rate of spontaneous abortion (16.2%) was close to expectation, and of foetal defect (2.7%) less than expectation. Overall, the problem was typical of many recent episodes of building illness in large modern office blocks. Our findings suggest that imperfect ventilation together with periods of high temperature and low humidity were contributory factors. The building was planned for open plan use and ventilated accordingly; subsequent partitioning of floor space into offices and cubicles interfered with free air movement and probably aggravated the situation.

BUILDING ILLNESS IN A LARGE OFFICE COMPLEX

1. Background

The investigation described in this report was undertaken at the request of the Treasury Board (TB) and the Public Service Alliance of Canada (PSAC), employer and largest union respectively, of Canadian federal civil servants. Our task was to provide a comprehensive description of the health and environmental complaints of federal employees working in Les Terrasses de la Chaudière, a massive new office complex on the Quebec bank of the Ottawa river over from the Houses of Parliament. Limited environmental measurements were also to be made as a clue to possible etiology. The nature of the complaints, as roughly described to us at the outset, was fairly typical of the many recent epidemics, sometimes referred to as building illness or tight-building syndrome, in large new office blocks in Europe and North America. These outbreaks are characterized by poorly defined but mainly irritative symptoms of the upper respiratory tract, eyes and skin, often accompanied by more general complaints of fatigue, malaise and depression (1, 2, 3). At Les Terrasses, and in some other episodes, there was also much concern about possible effects in pregnancy leading to abortion, stillbirth and birth defects.

The employees' complaints were of 6 years' standing, having begun soon after the building was first occupied in 1977; they were giving rise to much anxiety and seriously impairing employer-employee relations. The study was jointly funded by the Board and PSAC, both of which participated in a Steering Committee which met with us periodically to review progress. However, responsibility for design, conduct and analysis of the project remained ours alone. We received the go-ahead on February 1, 1983, with one year for the field work and two more months for analysis and draft report. Our Final Report (4) was formally submitted to the Treasury Board and PSAC in July 1984.

Our study design was descriptive rather than analytic. We sought to estimate the incidence and prevalence of health and environmental complaints by age, sex and certain other personal characteristics in relation to: a) time variables, such as date of employment, season, day of week, hour of day and b) location variables, such as type of office, floor, aspect, proximity to office machines. Since it was possible that employees with symptoms might have left the service, been transferred to another building or moved within the complex, both past and present employees were studied and an effort made to record their complaints at every work location. We decided against the study of any control building, partly for reasons of economy but, more importantly, because the level of emotional concern at Les Terrasses was such that no useful comparison with any other building(s) seemed possible. We concentrated instead on internal comparisons in the belief that if environmental factors were responsible for the symptoms, they might well be non-uniform in time or space. If the problem was wholly psychogenic, which seemed very unlikely, we saw no way of proving or disproving it. However, advantage was taken of certain important sets of data against which comparisons could be made. These included a) answers to questions on general health from the Canada Health Survey 1978-79 (5), b) answers to questions on job satisfaction from a study of Quebec civil servants (6) and c) preliminary results on the outcome of pregnancy from a large contemporary investigation in Montreal (7).

2. Materials and methods

2.1 Health survey

Sampling procedures. Each department provided a list of present and

past employees as of March 31, 1983, including the full name, sex, date of birth, present work location, home address, date of start and date of termination, where applicable, at Les Terrasses. The lists of present employees contained approximately 5300 names. We selected all female employees born between 1950 and 1956 (922 persons) and a 10% random sample of all other employees (448 persons) - 1370 in all. The special female stratum is referred to below as the SFS group. The sample was stratified in this way to maximize information on pregnancies and to reduce age, sex and related differences in analysis. The lists of past employees included approximately 5000 names; they were of uneven quality and did not permit any stratified method of sampling. A 20% random sample (994 persons) was selected. Of these, 547 were eligible for inclusion in the study in that they were listed in the current Gatineau-Hull-Ottawa telephone directory; had surname, first name or initial and address compatible with that given by department; and had no more than two apparently correct telephone numbers for the name as supplied to us.

Questionnaires. In the light of background information obtained at meetings with various employee groups, a questionnaire was developed to evaluate systematically the health complaints of current employees and their perception of environmental conditions at their various work locations. The questionnaire was pre-tested among employees in a building in Montreal where similar complaints to those at Les Terrasses were being experienced. The main questionnaire, intended for the current employees, comprised four main sections: personal data and characteristics; environmental complaints; health complaints; and pregnancy (women only). Information on environmental and health complaints was recorded for each work location.

After three or more reminder phone calls to those who had not returned the questionnaire, some basic information was asked in the form of a short questionnaire which addressed the issues of (1) health at Les Terrasses; (2) present work location and environmental conditions; (3) pregnancy (women only); and (4) reasons for not having completed the main questionnaire. The questionnaire used for past employees contained the same categories of information as the main questionnaire but was adapted for administration by telephone. At least four attempts were made to contact each individual.

Response. Of the 1370 names selected from current employees, 151 had already left the service when the survey began and 58 were on extended leave. From the remaining 1161 persons, 875 long questionnaires were returned, a response rate of 75%. This was supplemented by follow-up of non-responders who were asked to complete the short questionnaire. In all, at least some information was obtained from 94% of the sample. The subjects for whom no information was obtained, either by long or short questionnaire, included only 5 who actually refused to participate. The remainder included some who received a copy of the questionnaire but then left the building (either on extended leave, retirement, job transfer or promotion), and a small number whom we were unable to reach because they had moved station or there was no answer after several attempts.

During the telephone inquiry of past employees, carried out from November 1983 through February 1984, we identified 110 persons who did not meet our criteria; 23 were currently employed in the complex; 71 had never worked at Les Terrasses; 14 had moved out of our geographic area; and 2 were deceased. A large number (156) of other apparently good telephone numbers proved to be incorrect or disconnected. Of the remaining 281, interviews

... yielding a response rate of 75%. Nineteen persons declined to participate and the remaining 51 could not be contacted despite four or more attempts.

2.2 Environmental assessment

Floor classification. The floors in each tower were classified first on the basis of aspect (N, S, E or W) and each quadrant subdivided into perimeter (12 ft from external wall) and core. Next, consideration was given to whether an open or closed office configuration prevailed within the eight zones on each floor. If 40% of a zone comprised offices, the area was considered closed. Thus, four main patterns could arise: core closed, perimeter open; core open, perimeter closed; entirely closed; or entirely open. This classification suited the north and central towers well, but the east tower being more extensive was divided into three, north-east, south-east and link. Thus, four towers and a central zone (link) resulted for sampling purposes. Because of the terraced nature of the complex, zones present on lower floors were not always present higher in the structure.

Sampling and analysis. Limited time and resources precluded extensive investigation of all the environmental factors potentially implicated. Formaldehyde had already been studied by Health and Welfare Canada with levels all below 0.08 ng/m3 (0.07 ppm). Our studies were therefore limited to temperature, relative humidity, total particulates and total hydrocarbons - of necessity, all in the winter, 1983-84. Nine floors and sixteen pairs of specific worksites were classified in September 1983 as good or bad on the basis of preliminary analysis of the health questionnaires then available. Measurements on these floors and locations were then made 'blind' by the environmental study team, as described below:-

Temperature and relative humidity were each measured once with a psychrometer at mid-morning and mid-afternoon at each site on two consecutive workdays.

Total particulates, including fibres and fungal spores, were collected on open faced 0.8 micrometer pore-size cellulose acetate membrane filters (Millipore, MAW P037) using a Gilian air pump operating at one liter per minute during two consecutive workdays. The number of particulates, fibres and fungal spores was determined by phase contrast microscopy at 430 X using a technique recommended by NIOSH to measure airborne asbestos fibres (8). Random samples were examined by transmission electron microscopy.

Total hydrocarbons were sampled on activated charcoal at 50 ml per minute with a Gilian air pump during two consecutive workdays. The total volume of air sampled at each site was kept constant. To simplify the analysis, it was assumed that most of the organic compounds in the environment were aliphatic hydrocarbons (9). The charcoal was desorbed with carbon disulfide and the eluant analysed with a gas chromatograph equipped with a flame ionization detector. An estimate of the total hydrocarbon content of each sample was obtained based on an octane calibration.

Ventilation and air distribution patterns were determined by a tracer gas method using sulphur hexafluoride (SF6). Despite the non-toxicity of this gas, it was thought prudent to conduct these tests during weekends only; the floor ventilation systems were then functioning as usual but penthouse fans were not. Sulphur hexafluoride was released in the mechanical room of each selected floor to obtain an ambient floor concentration of approximately 50 ppb. The rate of decay was determined by monitoring SF6 concentrations over a four-hour period by sampling worksite air in polypropylene bags with

Gilian pumps. The SF6 concentrations were determined with a ... gas chromatograph (AID) equipped with an electron capture detector (detection limit 0.1 ppb). Dynamically prepared SF6 gas standards (Metronics Dynacalibrator, model 340) were generated daily for calibration of the chromatograph. The results obtained were used to calculate effective ventilation rates which in turn reflected air distribution patterns of each floor. This type of measurement was not possible at the sixteen paired worksites.

The volume of outdoor air supplied to each selected floor was determined using the Pitot tube traverse method on each supply duct. Occupied floor volumes and areas used in subsequent calculations include the plenum but not service cores, elevator shafts and stairwells.

The results of the environmental study were to describe the selected worksites in terms of the four environmental factors and two ventilation parameters, and to rank them in overall quality. The ranking obtained was largely subjective and based on the assumption that each factor or parameter was equally important. The rank assigned applied only to the three-month period of the survey though it was evident that environmental conditions vary appreciably from season to season and from day to day.

2.3 Statistical analysis

Responses to the health questionnaires were coded, entered on magnetic tape and the files subjected to standard data cleaning procedures. Analyses were performed using statistical packages available on the McGill Amdahl computer. Respondents to the long questionnaire were asked to record their complaints about health and the environment for each location they occupied while at Les Terrasses. The 875 respondents had occupied a total of 1843 person-locations, an average of about 2 each. Tabulations of complaints used these person-locations as the unit of analysis. In certain tables, only the first person-locations of respondents in the SFS group were used. Where complaints were compared to environmental measurements, only the location occupied at the time of the environmental survey was considered. As this was primarily a descriptive survey, significance tests were performed infrequently. Where presented, two tailed levels of significance are given. The principal component analysis reported in Section 3 was performed using the SPSX package. Estimation of population baseline frequencies of symptoms of anxiety and depression from the Canada Health Survey (CHS) were computed from the Ontario and Quebec respondents using weights appropriate to the sample design.

3. Findings

3.1 Health surveys

The age and sex distribution of current employees was similar whether they answered the long or short questionnaire (Table I). Three-quarters of the respondents were females aged 25-34, largely due to the sample weighting. The past employees were slightly older with more equal representation of the sexes. Subsequent results will refer to current employees completing long questionnaires unless otherwise stated. 46% of the women and 11% of the men were administrative support staff (mostly clerical); the remainder held mainly professional and managerial jobs. 39% smoked cigarettes and 1% cigars or a pipe.

to a question about health at Les Terrasses, 47% reported deterioration, 47% no change and only 1% improvement; 5% did not respond. Of those whose health deteriorated, 75% stated that they had seen a family physician, 9% had reported to the Health Unit and 9% applied for a transfer to another building or relocation within the complex. 24% of employees reported having been absent on one or more occasion because of health problems caused or aggravated by working at Les Terrasses. Somewhat fewer (29%) of past employees stated that their health had deteriorated.

The prevalence of health complaints is shown in Table II in descending order of frequency from nasal symptoms (49%)to "other" symptoms (7%). Within each symptom group, the relative frequency of the various specific complaints reported is also shown. The prevalence of symptoms was somewhat lower among ex-workers, a disparity only partly explained by differences in age and sex of the two groups. The symptoms were generally experienced during the course of the working day and not in the evenings or on weekends. Most respondents had their symptoms in all seasons but among a minority discriminating, winter was worst. Frequency of complaints about the environment is shown in Table III; the most common concerned ventilation, with noise and lighting frequently mentioned.

Frequency of psycho-physiological symptoms of anxiety and depression were measured using MacMillan's Health Opinion Survey, a widely used series of questions, asked also in the Canada Health Survey (CHS) (5). In all, 4.8% of men and 7.9% of women from Les Terrasses experienced frequent symptoms of anxiety and depression(as defined in the CHS), compared with 1.6% and 4.2% in Ontario and Quebec men and women in the CHS. Further analysis did not suggest that these differences were the result of confounding by age or type of occupation. Responses to questions taken from a study of Quebec civil servants (b) showed a slightly lower level of job satisfaction among the Les Terrasses employees than their provincial counterparts.

From the long and the short questionnaires for current employees and from the inquiry among past employees, we learned of a total of 654 pregnancies, of which 222 were in women who at the time of conception were employees at Les Terrasses. Thirty-six (16.2%) of these ended in spontaneous abortion (95% confidence limits 11.6-21.7%). There were no stillbirths but of the 186 live births, 5 (2.7%) were reported as having developmental defects. In the current investigation of pregnancy outcome based on 90% of all births in Montreal, 1982-84, the abortion rate for women in selected clerical occupations lay between about 15.6 and 16.7% (7). The frequency of spontaneous abortion is affected by many variables and comparable rates cannot therefore be readily or precisely defined. However, several other reports (e.g., 10, 11, 12) indicate that about 15% of recognized pregnancies end in spontaneous abortion. Of live and still births in the Montreal survey, 5.8% had a developmental defect. There was, thus, no evidence that work at Les Terrasses had an adverse effect on pregnancy.

3.2 Environmental studies

In Table IV, it will be seen that temperatures ranged from 19 to 26.5°C on the nine floors investigated and from 21 to 26.5°C at selected worksites. The temperature at most of the sites monitored remained relatively uniform during the workday and exceeded the 23.5°C recommended by ASHRAE on few occasions. Relative humidity ranged from 14% to 39%. Most of the particulates sampled during the investigation were fungal spores. Little or no fibrous material was observed. Total particulate counts ranged from 0.01 to 3.54 particles/cc and exceeded 2.0 particles/cc on few occasions. Total hydrocarbon concentrations ranged from 0.01 to 2.64 mg/m^3 and rarely exceeded 1.0 mg/m^3. There are no existing norms for total hydrocarbons or for total particulates for indoor environments.

Outdoor air was supplied to the building by the ventilation system filtered, humidified and temperature controlled; supply rates and distributions at selected worksites are summarized in Table V. Comparison of these results with the recommended rate of 0.15 cfm/ft^2 (Public Works Canada) indicates that the amount of outdoor air supplied was adequate on 6 of the 9 floors. None of the 3 floors in Tower 1 received the amount of outdoor air recommended for areas in which smoking is permitted. Outdoor air distributions determined at selected worksites by the tracer gas method, varied significantly on some floors characterized by a mixed configuration of open areas and closed offices. The remaining floors, characterized by a uniform layout, had a uniform distribution of outdoor air. These results suggest that a mainly closed or open office configuration is a pre-requisite for satisfactory air distribution.

3.3 Health and environmental correlations

In this section, the distribution of symptoms is related to office location and configuration, and to the rather limited environmental data described in Section 3.2. Our approach was first to take each of the main symptoms separately, and then to define 4 groups of symptoms (syndromes), each characteristic of a specific etiological mechanism. Having examined the prevalence of these syndromes and their relation to work location, the analyses were repeated with a single, strictly defined syndrome, considered typical of "building illness". Finally, the prevalence of the syndromes and of building illness was examined for those working on the 9 floors and 16 paired work locations where environmental measurements had been made. Where possible, the analyses were confined to the SFS group to avoid the confounding effects of age and sex.

Individual symptoms. Each of the symptom groups shown in Table II was examined a) by office configuration and location (tower, core/periphery, aspect), proximity to machines, type of work and b) by the type of environmental complaints reported. Systematic effects were found only for type of office (Table VI(a)). For every symptom (except 'other'), women working in cubicles had a higher rate of complaint than those in other types of office configuration. In a related analysis, it was seen that women in their own cubicle were also most likely to report environmental complaints (Table VI(b)). However, the differences between office types, although consistent, were small, with a high rate of complaint in all types of workplace. Only 10% of women in the SFS group in their own cubicle had no symptoms; this rose to 15% for women occupying their own office and to 19% for those in an open work area. Environmental and health complaints were closely related: among those in the SFS group who complained about their workplace, 94% also had symptoms; of those who did not complain about the environment, only 56% reported trouble with their health. With the exception of eye symptoms (which were most frequent amongst those who complained of lighting) symptoms were most frequent amongst those who complained about features of their office, 97% of whom also complained about their health.

Syndromes. Medical and physiological principles suggested that the various symptoms under study were unlikely to be caused by the same agent or mechanism. Whatever the agents responsible, there was no reason to suppose that they would be distributed in the same way throughout the complex. Four categories of symptoms were therefore defined in order to search for clusters of affected workers whose work location might help to identify the cause of the problem. The syndromes were defined as follows:-

a) Irritant: Persons with specified symptoms(s) in nasal, throat, contact lens or eye categories - excluding blurred vision.

b) Toxic: Persons with nausea, vomiting, headache, fever, chills, general malaise, drowsiness, faintness, difficulty in concentration or blurred vision.

c) Skin: Persons with any specified symptom in the skin category.

d) Stress: Persons complaining of anything under the stress category.

Examination of the prevalence of these syndromes by age and sex suggests that women had somewhat higher rates than men and that those in the oldest age group (55 years or more) tended to complain less than other workers of the same sex. Within the SFS group, prevalence was higher for each syndrome for women working in a cubicle. Woemn in closed offices had the lowest prevalence of irritant or stress syndromes, and those in shared areas the lowest prevalence of skin problems (Table VI(c)). No other relation of interest was observed between syndrome and location of office, nor was there any evidence that prevalence was lower amongst those who had started work at the complex in recent years.

Building illness. The analysis to this point had indicated a possible relationship between office type and health complaint, but little other systematic distribution of symptoms by work location. As the pattern of the relation between symptoms and office type did not manifest itself clearly in the analysis of the four syndromes, it was decided as a final step to examine a more demanding syndrome, typical of "building illness". For this approach, a respondent qualified as a case if he (or she) complained of either nasal or throat symptoms and eye (or contact lens) symptoms but not of any stress symptom: these cases, it was argued, reflected environmental irritation uncomplicated by psychological factors.

The prevalence of the syndrome was examined by type of office as well as office location (core/periphery), and a classification of whether the floor was entirely open, closed or mixed. Women in the SFS group had lower rates (14%) of building illness in their first work location if they worked in an open (shared) area; the rates in closed offices and cubicles were very similar (19%) (Table VI(d)). No relation of importance was found with the other factors examined.

Principal component analysis. Interpretation of the relation between office type and "building illness" was complicated by the tendency of women working in cubicles to complain more frequently than others of all symptoms, including those such as menstrual irregularities for which it is difficult to conceive a direct environmental cause. An exploratory attempt was therefore made to examine inter-relationships between symptoms using the statistical technique of principal component analysis. The first component extracted from the correlation matrix of health complaints was found to reflect a general tendency to complain of all symptoms included in the questionnaire. Scores for this component, computed independently of type of office, were nevertheless found to reflect the office configuration of the women in the SFS sample, those in cubicles having the highest complaints score (as expected from Table VI), those in open areas having an intermediate score and those in closed offices the lowest score (see Table VII). A weak second component was also extracted, which may be regarded as independent of the overall tendency to report symptoms. This second component was positively weighted for items reflecting eye irritation, complaints about contact lens and, to a lesser extent, nasal symptoms and negatively weighted for digestive and flu-like symptoms, stress and general symptoms such as drowsiness and difficulty in concentration. On this component, those in cubicles had positive scores due to a preponderance of irritant symptoms, while those in open areas had a greater tendency to complain of the negatively weighted symptoms (digestive, stress) than of eye and nasal irritation.

This analysis was exploratory and it should be noted that the second component had little statistical significance. However, the similarity between the a priori definition of building illness and this second component independently extracted from the data, adds weight to the conclusion that those working in cubicles tended to report a specific pattern of complaint (irritant rather than stress) over and above their tendency to report symptoms across the whole range.

Environmental assessments. The relations between the measurements made on the nine floors and each of the syndromes (including building illness) are shown in Table VIII. In an array of this size and with a small number of data points, one or two large correlations may be expected by chance; nevertheless, building illness was positively related to within-day ranges of humidity and temperature. The correlations between syndrome prevalence and environmental rank were small or negative. Measurements of the 16 pairs of work sites showed no difference between cases and controls (Table IX).

4. Discussion

The findings from this study can be briefly stated. A very high proportion of employees at Les Terrasses de la Chaudière reported health and environmental complaints related to their place of work. The symptoms were mainly associated with irritation of the nose, throat, eyes and skin, often accompanied by impaired sense of well-being. This picture agrees closely with other epidemics of tight building syndrome and strongly suggests that physical and chemical factors in the office environment are implicated. Concerns about pregnancy probably resulted from the high level of prevailing anxiety; certainly our data showed no indication of any adverse effect.

Such differences as were observed in relation to age, sex and type of employment shed no light on possible causes. Attempts to localize the problem in terms of tower, floor, quadrant, aspect, etc., were also negative. The long-standing nature of the problem and imperfect memory may have obscured differences of this kind; the employees had moved location often and may have left or been transferred, in part because of their complaints. Despite all this, there were systematic differences, albeit small, which suggest that there was some correlation between the occurrence of building illness and measurements of temperature and humidity, and that those who worked in cubicles separated by room dividers fared worse than those in closed offices or open areas. These patterns point to ventilation quality and control as important factors.

A striking feature of building illness is the similarity of the clinical picture wherever it has been reported. It has generally three components, the first reflecting irritation of the mucus surfaces, skin and eyes, the second impairment of well-being and work capacity and, the third, direct and indirect expressions of deep anxiety. The first element could be explained by the accumulation of chemical and particulate irritants, including tobacco smoke, together with periods of high temperature and low humidity. The agents responsible may be numerous and specific but adequate ventilation and air conditioning would surely remove them. The second component, comprising more general symptoms of headache, drowsiness, exhaustion, sleeplessness, irritability, etc., is more psychological in nature: these are the common experience of all who have worked for long periods in overheated rooms with little air movement, especially if accompanied by imperfect artificial lighting, noise and other distractions. Few people like to work in modern office blocks which fail to provide a reasonable degree of control of the working environment. Clerical work in large government offices is detailed and demanding yet offers little scope for self fulfilment. The rules and regulations of a hierarchical administration may not always

encourage personal initiative and individuality. These characteristics of work are symbolized and reinforced by buildings such as Les Terrasses. The third component is more serious because it probably reflects the feelings of frustration, anger and alienation experienced by employees subjected to unsatisfactory working conditions by impersonal and apparently unsympathetic authority. Such feelings are probably close to the surface anyway. In these circumstances, it is not difficult to appreciate that large groups of employees, many of whom are experiencing clear physical symptoms, come to the collective belief that they are indeed being poisoned, perhaps by agents capable of causing foetal damage, or even some life-threatening illness.

The implications of all this are that the symptoms of building illness, despite their apparently minor nature, deserve to be taken seriously. The problem demands general rather than specific solutions. It is hardly more useful to identify the many potentially irritating agents which pollute the air of inadequately ventilated sealed buildings (probably in very low concentrations) than it would have been to identify the countless types of bacteria in the polluted water supplies of our cities a century ago. Pure air is probably as necessary as pure water; both depend on appropriate engineering. The broader psycho-social question of whether large office complexes can ever provide a wholly satisfactory working environment is beyond the scope of this paper. As we shall not get rid of such buildings in the foreseable future, much will depend on employer-employee relationships. These are particularly difficult to maintain in large organizations, where the employees and employer are strangers to one another. In these circumstances, years may pass before a serious grievance is investigated let alone controlled. This is a common feature of "building illness"; it magnifies the problem, confuses the picture and handicaps etiological research.

At Les Terrasses, the element of delay was a major difficulty in our inquiry. We were wholly dependent for information on essentially subjective responses to questionnaires. Memory coloured by recent emotional events was not adequate to identify reliably circumstances associated with the onset of symptoms so we were forced to rely on prevalence rather than incidence - the more discriminating index. This, and the problems resulting from selective movement of work location within and outside the complex, undoubtedly obscured any patterns of incidence there may have been. Not surprisingly, our attempts to correlate symptom prevalence with environmental measurements failed. The environmental survey was not extensive and conditions on the nine floors tested at the end of 1983 bore little relation to those to which the employees were exposed when their symptoms began. The lessons are clear: buildings in which there is evidence of environmentally-related health complaints call for immediate investigation. Sensitive and reliable measures of air quality and ventilation should be used and more objective methods for health assessment developed and applied. We believe that eye signs, especially in contact lens users, could prove to be a most useful physiological index.

5. Acknowledgement

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TABLE I. AGE-SEX DISTRIBUTION OF RESPONDENTS (%)

Age (y)	Present		Past
	Long form	Short form	
Male employees			
15-24	5	1	9
25-34	50	17	22
35-44	60	19	41
45-54	37	6	11
55-64	16	4	22
65-74	-	-	3
> 75	-	-	1
All	168	47	109
Female employees			
15-24	22	5	15
25-34	610 *	137	46
35-44	41	13	19
45-54	19	9	11
55-64	15	3	5
65-74	-	-	-
> 75	-	-	2
All	707	167	102

* Includes 582 in special female stratum (SFS).

TABLE II. PREVALENCE OF HEALTH COMPLAINTS (ALL LOCATIONS)

Symptom group	Prevalence (%) *	Distribution within group (%)
Nasal	49 (28)	Congestion(45), sneezing(42), sinus problems(39), runny nose(37), hay fever(20), bleeding(18), other(9)
General	48 (40)	Drowsiness(64), difficulty in concentration(57), dizziness(31), faintness(19), other(5)
Aches	47 (39)	Headache(83),backache(32),muscular/joint pain(19),other(7)
Eye	44 (25)	Irritation(46),burning(44),blurred vision(40),dryness(37), redness(33),watering(20),puffiness(13),other(10)
Stress	42 (21)	Exhaustion (71), sleeplessness(40), irritability(39), anxiety(35), depression(31), other(7)
Throat	38 (21)	Dry throat(63), scratchy throat(36), sore throat(35), dry cough(32),other (9)
Skin	27 (9)	Dryness(73),irritation(26),flaking(22),rash(21),other(17)
Digestive	24 (10)	Nausea(49), stomach-ache(35), diarrhea(29), constipation(29), indigestion(25), vomiting(8), other(9)
Flu-like	21 (14)	General malaise(59), chills(48), fever(35), other(11)
Breathing	20 (13)	Breathlessness(60), chest tightness(38), wheezing(21), asthma(8), other(13)
Contact lens	16 (2)	Discomfort(68), deposits(32), cleaning(23), pain(21), other(31)
Other	7 (4)	Specific complaints noted by individual (98)
Menstrual (females only)	20 (6)	Irregular periods(54), premenstrual tension(45), heavy menstrual flow(33), other(16)

* Rates for past employees underlined and in brackets.

TABLE III. PREVALENCE OF ENVIRONMENTAL COMPLAINTS

Troublesome aspect	Prevalence %	Distribution within group (%)
Ventilation	73	Dryness(56), temperature(54), odours(45), humidity(14), other(19)
Noise	42	Office equipment(62), ventilation system(36), other(38)
Lighting	37	Insufficient(48), glare(42), too bright(20), flicker(15), other(7)
Other (specified)	25	Privacy(59), distractions(55), view(30), claustrophobia(23), oppressiveness(20), other(10)
Office	24	Tidiness(48), partitions(44), decor(25), other(29)

TABLE IV. RESULTS OF ENVIRONMENTAL ASSESSMENTS

Tower-floor	Temperature (°C)	Relative humidity (%)	Total particulates (particles(cc)	Total hydrocarbons (mg/m^3)
1-12	20.5-23.0	25-34	1.01-2.30	0.06-0.23
1-14	21.0-24.0	25-30	0.23-0.74	<0.01-0.01
1-15	20.5-24.3	27-38	1.35-2.08	0.01-0.29
3-9	21.0-22.5	20-31	0.41-1.62	0.12-
3-10	19.0-25.0	20-34	0.39-1.35	0.12-0.20
3-18	21.5-24.0	31-39	0.65-1.51	--
4-7	22.0-26.0	24-33	0.91-2.26	0.12-2.64
5-10	22.8-25.0	23-32	0.67-1.77	0.04-0.08
5-28	20.5-26.5	26-36	0.39-1.24	0.02-0.06
Selected worksites	21.0-25.5	13-33	0.23-3.54	0.01-1.78

TABLE V. OUTDOOR AIR SUPPLY RATES AND DISTRIBUTION

Tower-floor	Measured outdoor air supply (cfm/ft2)	(cfm/person)*	Measured ** ventilation (air changes/hour)	Effective ** ventilation (air changes/hour)
1-12	0.10	15.0	0.54	0.25-0.57
1-14	0.10	15.0	0.53	0.25-0.54
1-15	0.12	18.0	0.61	0.35-0.51
3-9	0.20	30.0	1.04	0.70-0.80
3-10	0.16	24.0	0.83	0.39-0.50
3-18	0.16	24.0	0.85	0.27-0.38
4-7	0.13	19.5	0.67	0.31-0.34
5-10	0.15	22.5	0.78	0.39-0.97
5-28	0.14	21.0	0.73	0.57-1.29

* assuming 150 ft^2/person

** not measured under comparable conditions (see 2.2)

TABLE VI. PREVALENCE (%) OF COMPLAINTS AND SYNDROMES BY TYPE OF OFFICE, SFS GROUP, FIRST WORK LOCATION

	Type of work location: Closed office (n = 80)	Cubicle (n = 268)	Open area (n = 191)
(a) Health complaints			
Nasal	40	50	44
Throat	28	42	37
Eye	44	49	41
Contact lens	19	25	17
Breathing	16	20	19
Skin	30	33	24
Digestion	15	28	20
Aches	35	50	48
Flu-like	20	22	19
Stress	29	44	40
General	36	58	42
Other	13	6	8
Menstrual	18	21	19
None	15	10	18
(b) Environmental complaints			
Noise	42	42	40
Ventilation	75	76	65
Lighting	43	44	35
Office	15	26	22
Other	17	29	25
None	19	15	24
(c) Syndromes			
Irritant	63	71	66
Toxic	61	77	60
Skin	28	31	22
Stress	29	44	40
(d) Building illness	19	19	14

TABLE VII. SYMPTOM SCORES COMPUTED FROM PRINCIPAL COMPONENT ANALYSIS, SFS GROUP, FIRST WORK LOCATION

Office type (n)	Mean scores computed from Component 1	Component 2
Closed office (80)	-0.74	0.14
Cubicle (268)	0.47	0.35
Open area (191)	-0.25	-0.68
Difference between means (F test)	4.90	1.00
p	< .01	< .05

TABLE VIII. CORRELATIONS BETWEEN ENVIRONMENTAL QUALITY AND PREVALENCE OF VARIOUS SYNDROMES: ON 9 SELECTED FLOORS

	SYNDROMES				
	Irritant	Toxic	Skin	Stress	Building illness
Temperature - departure from 22°C	.182	.406	.469	-.217	.285
Temperature - within day range	-.343	.081	-.207	-.489	.360
Humidity - departure from 50% RH	-.349	.300	-.165	-.210	-.290
Humidity - within day range	.149	-.365	-.034	-.178	.663
Total particulates	.445	.323	.223	.054	-.150
Organic vapours	-.359	.059	-.495	-.219	-.216
Ventilation - uniformity	-.251	-.230	-.350	-.217	-.218
Ventilation - fresh air	.131	.485	-.034	-.163	-.298
Environmental score (mean of ranks)	-.115	.225	-.153	-.476	.066
Rank of score	-.173	.189	-.382	-.465	-.101

TABLE IX. MEAN ENVIRONMENTAL MEASUREMENTS AND "BUILDING ILLNESS" (16 CASE-CONTROL PAIRS) *

	Cases *	Controls
	mean values	
Temperature:		
(1) Absolute difference from 22°C	1.5°C	1.3°C
(2) Within day range (°C)	0.7°C	0.7°C
Humidity:		
(1) Absolute difference from 50% RH	24.00%	25.00%
(2) Within day range (% RH)	2.00%	1.00%
Total particles (per cc)	1.12	1.55
Organic vapours	0.55 mg/m^3	0.54 mg/m^3

* Were defined in September 1983 on similar but not identical criteria to later building illness syndrome.

RELATING HEALTH AND ENVIRONMENTAL STUDIES IN A TIGHT BUILDING SYNDROME INVESTIGATION

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A two-phased study was undertaken to investigate health and environmental complaints in a large, modern, sealed office complex. An account of the epidemiological investigation and the associated environmental study has been presented earlier at this conference (McDonald et al).

The health surveys of present and past employees were conducted to fully characterize the nature and magnitude of the complaints. Preliminary analyses of the current employee questionnaire data were used in establishing the environmental sampling protocol. A limited environmental study was conducted to identify environmental factors which might be responsible for the complaints of the complex's occupants.

Incidence and prevalence rates of a pre-defined "irritation-type" syndrome were examined on a floor-by-floor basis in all towers of the complex. Ten floors were selected for environmental investigation. The environmental survey of these "good" and "bad" floors, as characterized by low and high frequencies of an irritation syndrome, consisted of two areas of study -ventilation and the measurement of specific air quality parameters.