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EFFECT OF CHANGES IN THE OPERATION OF A BUILDING'S VENTILATION SYSTEMS ON ENVIRONMENTAL CONDITIONS AT INDIVIDUAL WORKSTATIONS IN AN OFFICE COMPLEX

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An investigation of the relationship between the operating conditions of a building's ventilation systems and the indoor environment has been conducted. The investigation consisted in the random selection of one of three ventilation rates for each week of a six-week study period. The work environment was characterized by measuring the amount of outdoor air supplied ambient temperature, humidity, air velocity, concentration of carbon dioxide, total particulates, total organic volatiles, formaldehyde, nitrogen oxides and fungal spores. The results of the investigation showed that there is a good correlation between the amount of outdoor air supplied and the concentration of gaseous contaminants at individual workstations.

INTRODUCTION

Ideally, office building occupant satisfaction with his/her work environment could be achieved through an adequate control of temperature, humidity and air velocity at the workstation, by the effective control of chemical and physical agents that are present and the introduction of appropriate amounts of contaminant-free air into occupied spaces. In reality, in most modern office buildings, the air supplied to occupied spaces is a mixture of recirculated air and outdoor air whose amount is determined by the building's thermal load and meteorological conditions. In fact, it is common practice in mid-summer and mid-winter to minimize HVAC operating costs by markedly reducing the amount of outdoor air introduced into the building. Systems such as variable air volume ventilation systems further regulate the amount of air delivered to a specific workstation according to thermal requirements. In addition, the efficiency of ventilation systems in delivering this air to individual work spaces can vary significantly. Not surprisingly, ventilation system inadequacies are most often blamed for the occurrence of building-related illnesses. (1) However, irrefutable evidence supporting this contention is scarce and the optimal amount of outdoor air required to maintain occupant wellbeing and comfort has not been the subject of rigorously conducted scientific studies to date. (2-6)

An investigation whose purported objective is to establish the relationship between the operation of a building's ventilation systems, the concomitant indoor environment and occupant acceptance would, of necessity, involve an evaluation of the performance of the ventilation systems, measurement of pertinent environmental parameters and an assessment of occupant satisfaction. Such a study has been conducted. The relationship between the operation of one building's ventilation systems and its indoor environment is reported here. The occupants' response to these environmental conditions are reported elsewhere. (7)

STUDY BUILDING

The building selected for this study is a thirty-storey building built in downtown Montreal twenty-two years ago. Each floor is served by five perimeter-area and two core-area HVAC systems. The intake and exhaust for each system are located side by side between the 16th and 17th floors. The outdoor air supply is controlled by louvered openings, mixed with recirculated air, filtered, humidified (steam injection) or dehumidified (cooling coils). The amount of outdoor air introduced is determined by the building's thermal load and outside temperature. All HVAC systems function continually.

Four floors were selected for this study. Both open and closed concept offices were present. Open areas were separated by two-meter high screens. Closed offices were located mainly on the periphery of each floor.

Each week of the study period, the louvres controlling the amount of air recirculated by the core systems were adjusted to one of three settings. These settings were not known to the survey team and were intended to provide three pairs of identical ventilation system conditions.

SURVEY PROCEDURE

An equal number of closed and open office areas were selected for sampling on the four floors. A sampling site was located in each general area served by one of the five peripheral HVAC systems and five other sites were chosen in the core area. Sampling sites selected on each floor were similar in location and type to those chosen on the other three floors. One of the core outside air inlets was also selected for sampling.

The environmental parameters measured, instrumentation used, duration of sampling and number of sites selected were as follows:

Temperature/humidity	10 sites/floor; psychrometer; 4 times daily; 6 weeks
Air velocity	10 sites/floor; Kata thermometer; twice daily; 6 weeks
Carbon dioxide[1]	10 sites/floor; portable meter; 4 times daily; 6 weeks;
Total Dust[1]	4 sites/floor; filter and portable air pump; averaged over 3 days of sampling; 6 weeks;
TVOC's[1]	4 sites/floor; charcoal tube and portable pump; averaged over 3 days of sampling; 6 weeks;
Formaldehyde	1 site/floor; sampling badge; averaged over 3 days of sampling; 6 weeks
Nitrogen Oxides[1]	1 site/floor; sorbent tube and portable air pump; averaged over 1 day; 6 weeks;
Fungal Spores[1]	2 sites/floor; agar strip and Biotest sampling unit; 4-minute samples; 1 week;
Outside Air Supply	10 sites/floor; tracer gas (SF_6) decay method; 6 weeks
Air Recirculation	7 HVAC systems; CO_2 measurement; 6 weeks

[1] These air contaminants were also measured at one outside air inlet.

RESULTS AND DISCUSSION

The amount of outdoor air delivered to the floors during each week of the study was regulated by manipulation of the two core HVAC systems. Three of the HVAC systems serving the peripheral area did not admit outdoor air and the remaining two systems were fixed at approximately 65 and 75% recirculation of air. The overall percentages of air recirculated by all seven HVAC systems during the study are shown in Table 1. It is obvious from these results that the goal of obtaining three pairs of similar ventilation conditions for the floors was only partially achieved.

Table 1. Percentage Recirculation of Total Air During The Study

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
78.7%	83.8%	84.2%	60.7%	75.6%	89.8%

The impact of the weekly manipulation of the two core HVAC systems on various ventilation systems performance indicators is depicted in Figure 1. Thus, with one exception, the average amount of outdoor air supplied to the floors was apparently related to the operation of the HVAC systems. Unscheduled

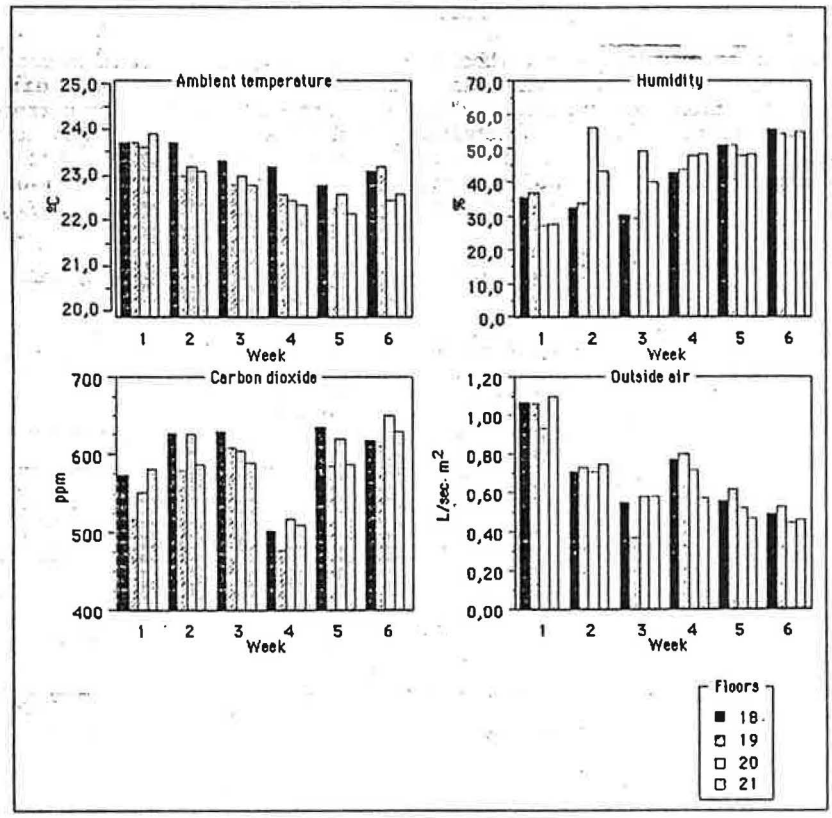

Figure 1: Distribution of the average daily value for selected environmental parameters on the four floors studied

work performed on the floors' windows, after hours, during the first week tracer gas tests, most probably inflated the values for the amount of outdoor air for that week. No apparent pattern is discernable for the first three weeks of the study and the values obtained did not vary significantly from floor to floor. Conversely, a repetitive pattern is observed during the last three weeks with the 19th floor benefiting from the most outdoor air. The four floors did not receive the amount of outdoor air prescribed by ASHRAE (0.75 L/sec. m^2) (8) during weeks 3, 5 and 6 of the study.

Carbon dioxide concentrations on any given floor in an office building is largely dependent on both its population and the amount of outdoor air delivered to it. The population of the four floors was relatively constant during the study and carbon dioxide levels did, in fact, mirror changes in the relative amount of the outdoor air supplied to the floors week to week (Figure 1). The highest levels and greatest individual concentration of carbon dioxide, 753 ppm, were indeed measured during weeks 3, 5, and 6 which were characterized by the inadequate amount of outdoor air delivered to the floors. However, in view of the presently accepted criterion of 1000 ppm for this gas in office areas (8), it was not possible to conclude, solely on the basis of CO_2 levels measured, whether or not the amount of outdoor air supplied to the floors was sufficient.

A weekly decrease in ambient temperature occurred throughout most of the study period and this trend was matched by a commensurate increase in humidity. Temperature measured at all sites varied by less than 1°C during any given workday and invariably met ASHRAE standard. (9) Humidity and air velocity were similarly acceptable.

The gaseous contaminants carbon dioxide, nitrogen dioxide, nitric oxide and volatile organic chemicals can be found in outdoor air and their indoor concentration was "normalized" by dividing the latter by the corresponding outdoor level. The values obtained for the gaseous contaminants apparently varied exponentially with the amount of outdoor air supplied to the floors. A plot of the logarithm of these values versus the corresponding amount of outdoor air supplied to each site shows a strong correlation (Figure 2).

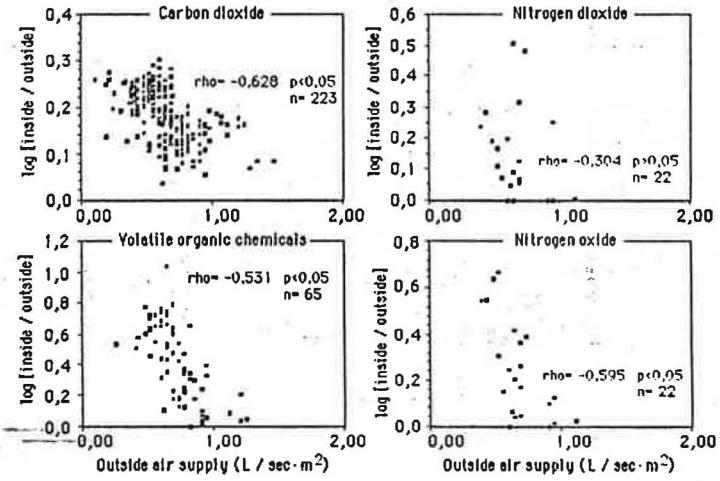

Figure 2: Distribution of the values of selected environmental parameters as a function of the amount of outside air supply

Formaldehyde, whose sources are mainly indoors, showed a similar albeit less strong relationship with the amount of outdoor air supplied. It is worth noting that none of the gaseous contaminants exceeded norms.

Indoor concentrations of total dust ranged from 6.8 to 57.6 ug/m^3 and were considerably less than outdoor air concentrations which averaged 540 ug/m^3. Similarly, the concentrations of fungal spores found indoors (6-53 CFU/m^3) were markedly less than those found outdoors (359 CFU/m^3). These results indicate that the HVAC systems filtration units were very efficient in removing particulate matter from the air introduced in the building.

CONCLUSIONS

The results of this investigation showed that, in aged buildings, with relatively constant populations, and with no unusual work activities, either in progress or recently performed, the concentration of gaseous contaminants such as carbon dioxide, nitrogen oxides, total volatile organic chemicals, formaldehyde, and possibly others are related to the amount of outdoor air supplied to the occupied spaces. In such buildings, the concentration of gaseous contaminants can be maintained at acceptable levels by ensuring that an adequate amount of outdoor is delivered to individual work stations.

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