CHARACTERISATION OF GARAGE-AIR RECIRCULATION IN A NEW BUILDING USING A TRACER

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ABSTRACT

Air recirculation in the new office and laboratory building of the Norwegian Institute for Air Research was discovered and characterised from a leaking sulphur hexafluoride cylinder stored in the garage. The garage/staging area was located at the far end of the right wing of the three-storey building, and was used for loading/unloading of equipment and for storage of equipment and compressed gas cylinders. Sulphur hexafluoride tracer was detected in the corridor on the ground floor right wing leading to the central reception area. Tracer was also detected in stairwells and in corridors and offices on the third floor of the building, all areas where automobile exhaust and gasoline smells had been occasionally reported. A routine deliberate tracer release in possible problem areas is suggested as a tool to help in evaluating ventilation system performance before a building is put into service.

INTRODUCTION

In Norway, evaluation of the ventilation system of a new building before it is put into service generally consists of spot checks by the ventilation contractor of supply and exhaust air volumes from the separate ventilation zones to confirm that the design values for air exchanges have been achieved. Proof of an adequate air exchange rate is assumed to demonstrate a level of ventilation sufficient for maintaining acceptable indoor air quality. Avoidance of recirculation in a ventilation system, however, is at least as important as an adequate fresh air exchange rate in achieving this goal. Recirculation, which is prohibited in the Norwegian Building Code [1], can occur as a result of poor placement of exhaust vents in relation to clean air intakes of a building. Transfer of air from a room or zone with poorer air quality to another room or zone with a higher air quality requirement is another form of recirculation. Often the result is the spread of unpleasant or even harmful substances throughout a building. A typical case is the recirculation of exhaust fumes from an attached garage. Though avoidance of recirculation is handled in the design phase by dimensioning an under-pressure in low air quality zones (more exhaust air than supply air in the zone), and by judicious placement of exhaust vents with respect to clean air vents in the buildings' exterior, testing for recirculation problems in the finished building is not standard procedure in Norway. It is therefore most often left to be discovered by users of the building perhaps long after the ventilation contractor has been paid and is finished with the project.

The building that was the object of this study houses the Norwegian Institute for Air Research (NILU). The building is a three-storey structure with combined laboratory and office space in two wings coming off an open atrium reception area. The garage/staging area is located at the far back end of the right wing of the building, and is used for loading/unloading of equipment from vehicles driven in and for storage of equipment and compressed gas cylinders. Five separate ventilation subsystems supply fresh air in the building, two for the left wing and three for the right wing, where most of the laboratory space is located. The building was completed in 1994 and was designed and built to be both environmentally friendly and energy efficient.

METHODS

Tracer concentrations were measured with a NILU custom-built microprocessor-controlled sulfur hexafluoride (SF_6) gas chromatograph (GC) with electron capture detector. The instrument is extremely sensitive, with a detection limit for SF_6 under 10 parts-per-trillion-by-volume (10 pptv). The entire system, including carrier gas, fits into a suitcase that can be taken anywhere for on-site measurements. Air change rates in rooms were determined using the tracer decay method [2]. Several millilitres of pure tracer gas were released into a space, mixed with a fan, and tracer concentration decay versus time was monitored at a point in the room. In an earlier study, this method yielded exchange rates in reasonable agreement with measurements of supply and extract air volumes provided by the ventilation contractor when the NILU building was put into service in 1994 [3]. The gas chromatograph has an automatic sampling function that allows for automated monitoring of tracer decay and determination of air exchange rates.

The leaking sulphur hexafluoride cylinder in the garage was discovered during tracer-decay air-exchange rate tests in rooms in the building when high background concentrations of sulphur hexafluoride were observed in areas leading from the garage. NILU performs atmospheric dispersion studies with sulfur hexafluoride as a tracer. Consequently, SF_6 cylinders are stored in the garage/loading area. SF_6 is not stored or used anywhere else in the building. Grab samples to characterise the recirculation of the tracer throughout the building were taken manually with 20-ml polyethylene syringes and analysed on the tracer GC.

The leak from the SF_6 cylinder was too small to be detected using a soap-bubble solution. The only way to stop the flux of tracer gas into the garage was to take the cylinder out of the building.

RESULTS

Measured air exchange rates for selected offices and laboratories in the building are listed in Table 1. The Norwegian Building Code requires a fresh air supply of 7 l/s per person plus 0.7 l/s/m^2 of floor space for a room furnished with low-emitting materials [4].

Table 1 – Measured air exchange rates.

Room type	Location	Floor area (m^2)	Building Code prescribed air exchange rate (hr^{-1})	Measured air exchange rate (hr^{-1})
Office	3rd floor, right wing	10	1.9	6.5
Office	2nd floor, left wing	10	1.9	6.5
Laboratory	1st floor, right wing	30	5.7	11
Laboratory	3rd floor, right wing	35	6.7	13

Figure 1 displays the floor plan of the first floor of the building. Grab sample locations are identified with letters in the figure. Tracer concentrations on the first floor from a series of grab samples taken in succession are shown in Table 2.

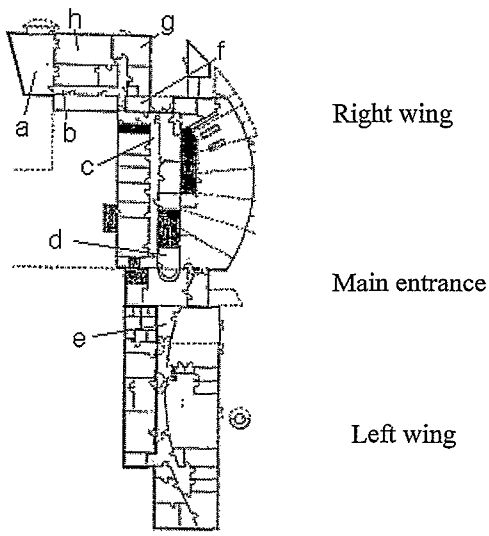

Figure 1 – Points where tracer concentrations were measured on first floor of building.

Table 2 – SF_6 concentrations on first floor of building

Sample location (from figure 1)	Description	Tracer concentration (pptv SF_6)
a	garage, tracer storage area	6000
b	hallway adjacent to garage	2700
c	hallway, right wing	1400
d	reception area	710
e	hallway, left wing	0
f	stairwell	750
g	laboratory	0
h	workshop	820

DISCUSSION

Table 1 shows that air exchange rates are well above the minimum values prescribed by the Norwegian Building Code. Based upon this data alone, the air quality in the building could be expected to be exceptional. A persistent odour of cigarette smoke in the hallways on the first floor, right wing of the building and gasoline and combustion exhaust smells occasionally reported in the reception area and in offices on the third floor, right wing of the building were qualitative evidence that recirculation was occurring from somewhere. There is a designated smoking room on the first floor in the opposite (left) wing of the building, but this was clearly not the source of the cigarette odour in the area in question. It was not immediately obvious where the cigarette odour was coming from because there are many rooms along the corridor between the garage and the reception area and all of the doors (including the door to the garage area) are normally closed. Investigation revealed that the garage area was used as an unofficial smoking area for some of the staff. Background concentrations of SF_6 confirmed significant recirculation of air from the garage area into the hallway and reception area, and up the back staircase (between the garage and reception area) to the third floor offices.

Background tracer concentrations in the building exhibited a maximum in the garage where the cylinder was stored. Concentrations in the hallway leading to the garage (with the connecting door closed) were approximately 45% of the values inside the garage. Concentrations in the reception area were about 10-15% of the SF_6 concentration in the garage. In addition to the values displayed in Table 2, tracer was also repeatedly detected in offices on the third floor, right wing of the building at concentrations of 2-3% of those in the garage. This was presumably the result of recirculation up the back staircase. It is interesting to note that no tracer was detected on the second floor, right wing of the building, or anywhere in the left wing.

The data presented here demonstrate the value of tracer measurements for diagnosing recirculation and quantifying contaminant transport in buildings. The case of the NILU building is particularly interesting because the room air exchange rates are so favourable and because much attention was given in the design and building stages to achieving an environmentally friendly facility. Clearly, recirculation from the garage area was not a design element of the ventilation system. It is also clear that in evaluating the final product before the building was put into service, emphasis was placed on achieving a high room air exchange rate without properly considering possible recirculation effects from zones with poor air quality. This study demonstrates that a high room exchange rate is not necessarily proof of adequate ventilation. In the case of a building with significant recirculation of pollutants, it is doubtful that increasing air exchange rates will lead to an improved indoor air quality. The recirculation problem must be addressed and corrected. In fact, with proper attention to recirculation, air exchange rates (and energy use) could probably be reduced at the same time a better overall indoor air quality is achieved.

Of course, use of a tracer in not necessarily required for detection of recirculation. Measurement of pressure differentials between rooms or sections or use of smoke or velocity sensors can be used. The advantage of using a tracer is that spreading of pollutants can be quantified and the recirculation paths over much greater distances can be investigated relatively easily. A simple test for recirculation could consist of a tracer release in a zone with poor air quality, such as a garage, followed by grab samples in suspected recirculation areas.

Requiring the ventilation contractor to demonstrate that recirculation is not occurring from possible problem areas as part of an acceptance protocol of a ventilation system would be a positive step. Though recirculation is often easy to detect after the system has been delivered and is in service (due to the presence of unpleasant odours, for example), it can be much more difficult to motivate the ventilation contractor to correct the problem.

ACKNOWLEDGEMENTS

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