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DEPOSITION OF AEROSOL PARTICLES IN BUILDINGS

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SUMMARY

The work described in this paper is concerned with measurement of the flow of tracer gas and aerosol particles in naturally-ventilated rooms. Measurements were carried out using SF_6 tracer gas and oil-smoke particles in a room providing different arrangements of window opening. Results indicated that particle exchange rates were higher than tracer-gas exchange rates. This was due to the deposition effect of particles on the surfaces of the room.

INTRODUCTION

Particulate pollutants in buildings can have damaging effects on the health of the occupants and studies have shown that indoor aerosol particles strongly influence the incidence of sick building syndrome [1]. Airborne particles are associated with allergies and it is known that they transport viruses and bacteria. Indoor aerosol particles are not only associated with outdoor sources (e.g., car exhaust emissions, coal and oil combustion, road dust, etc.) but also arise from a number of indoor sources (e.g., cigarette smoke, building materials, personal products, etc). Aerosol particles can deposit on surfaces of rooms or can be transported between zones; this can have serious effects in hospitals and buildings used by the micro-electronic and pharmaceutical industries [2]. Deposition of airborne particles in museums and galleries can lead to a perceptible soiling within a short period of time and ultimately result in damage to works of art.

The concentration of indoor aerosol particles can be reduced by mechanical ventilation using extract fans or by natural ventilation which allows air exchange between the indoor and outdoor environment via windows and doorways. The airflow, estimated using tracer-gas techniques[3], is not sufficient to describe the removal of particles as deposition rate, particle types, sizes, sources and concentrations must be taken into consideration.

An extensive literature search has revealed neither previous studies of the deposition of aerosol particles on surfaces of rooms nor investigations of particle exchange through large internal and external openings. This work is concerned with the measurement of aerosol particle in a naturally-ventilated room. Measurements of the flow of SF_6 tracer gas and oil-smoke particles were carried out in a room using different arrangements of window opening. This allowed single-sided and cross flow to be examined.

THEORY

Figure 1 shows a single-zone system. The concentration-decay technique was used to estimate the rate of tracer gas and particle exchange in a naturally-ventilated room. The method involves the initial injection of a tracer gas (e.g. SF_6) and particles (e.g. oil-smoke) into a zone and is followed by a period of mixing to establish a uniform concentration in the zone. The decay of SF_6 tracer gas and smoke particles is then measured using suitable detectors over a given time interval. The rate of decrease of SF_6 tracer gas and smoke-particle concentration is given by the following equations:

$$C_{g(t)} = C_{g(to)}\ e^{-It} \qquad (1)$$

$$C_{p(t)} = C_{p(to)}\ e^{-Pt} \qquad (2)$$

where $C_{g(t)}$ is concentration of tracer-gas ($\mu g/m^3$) at time t, $C_{g(to)}$ concentration of tracer-gas ($\mu g/m^3$) at time t equals zero; $C_{p(t)}$ is concentration of aerosol particle ($\mu g/m^3$) at time t, and $C_{p(to)}$ is concentration of aerosol particle ($\mu g/m^3$) at time t equals zero. I is the tracer gas exchange rate (h^{-1} or $\mu g/m^3 h$) and P is the particle exchange rate ($\mu g/m^3 h$). If the concentrations of the tracer gas and particles are plotted against elapsed time on semi-log paper, the negative slopes of the line are equal to I and P, respectively.

EXPERIMENTAL

Experimental work was carried out in the laboratory using a room as shown in Figure 1. The room was 11.6m x 2.65m with a maximum height of 4.2m. The room had windows fitted on opposite sides.

The experimental procedure involved injection of tracer-gas and oil-smoke particles into the room and was followed by a mixing period during which three desk fans were used. Multipoint-sampling units were then used to collect tracer-gas samples from the room for subsequent injection into an infra-red gas analyser. The accuracy of the measurements was estimated to be within ± 5%.

Particle concentrations and sizes were measured using a laser-particle monitor. This can measure particle concentrations in the range 0.0001 - 500 mg/m^3 for particle sizes range between 0.5 - 10 μm. in diameter. The results for the complete range of particle diameters are displayed every 5 seconds. The particle monitor was used with a memory card which could store data on particle sizes and concentrations for up to 8 hours. Data from the particle monitor were subsequently transfered to a computer for analysis.

Aerosol particles were injected into the room using a smoke generator. This was a microprocessor controlled system capable of producing oil-smoke particles between 0.1 - 2 μm in diameter with a mass medium diameter of < 0.3 μm.

RESULTS AND DISCUSSION

Experiments were performed in a room to determine tracer-gas and particle exchange rates for the following condition:

(i) All windows closed

(ii) One window half-open

(iii) Two windows half-open

(iv) One window fully-open

(v) Two windows fully-open

(vi) Three windows fully-open

The above window-opening arrangements were carried out in a room using single sided and cross flow. SF_6 tracer-gas and oil-smoke particles were injected into the room. Following a mixing period of 15 minutes, simultaneous measurements of tracer-gas and oil-smoke particle concentrations were performed using an infra-red gas analyser and a laser particle monitor, respectively. Diameters of oil-smoke particles were in the range 0.5 - 2 μm. Figures 2 - 5 show the variation of the concentration of tracer-gas and smoke particles (diameter 0.5 - 2 μm) with time for the conditions (ii) and (iv). The tracer-gas and particle decay curves were found to be simple exponential functions for all conditions.

Table 1 Experimental Results

Condition	Particle-Exchange Rate, P (μg/m³hr)			Tracer-Gas Exchange Rate, I		Particle Deposition Rate, α (μg/m²hr)			Temperature Difference (°C)
	d>0.5μm	>1μm	>2μm	(μg/m³hr)	(h^{-1})	d>0.5μm	>1μm	>2μm	
All windows closed	5.22	8.75	11.64	5.22	0.14	0	3.31	6.02	6
One window half-open	136.06	123.45	113.64	21.93	1.50	107.14	95.30	86.09	10
Two windows half-open	456.52	328.21	466.45	188.18	3.14	251.90	131.45	261.23	6
One window fully-open	384.26	296.19	374.51	185.62	2.98	186.48	103.80	177.32	9
Two windows fully-open	341.12	355.67	376.88	253.35	4.22	82.39	96.05	115.96	8
Three windows fully-open	715.93	731.81	766.26	468.76	8.46	232.04	246.9	279.29	8

Table 1 shows tracer-gas and particle exchange rates for conditions (i) to (vi). It is clear from this table that the particle exchange rates were higher than tracer-gas exchange rates. The difference in tracer-gas and particle exchange rate is due to the depositon (or adsorption effect) of particles on the surfaces of the room. This was estimated using the following equation:

$$\alpha = [P_{(t)} - I_{(t)}] * V / A \quad (3)$$

where α is particle deposition rate ($\mu g/m^2h$),V is volume of room (m^3) and A is total surface area of room (m^2).

Deposition rates for various particle sizes are given in Table 1. The deposition rates were in the range 0 - 251.9 ($\mu g/m^2$ h) for $d > 0.5$ μm and 6.02 - 279 ($\mu g/m^2$ h) for $d > 2$ μm. The results indicate that air exchange rate is not sufficient to describe particle flow rate as particle dispersion rate and size of particles should be taken into consideration. Equation (2) should therefore be modified to take into account the deposition effect. Depending on the outside condition, ventilation air entering the room could contain a particle concentration sufficiently large to influence the particle decay curves. The concentration of particles entering the test room during our experiments was found to increase as window openings became larger.

CONCLUSIONS

1. The results showed the particle exchange rates were higher than tracer-gas exchange rates. This was due to the deposition effect of particles on the surfaces of the room.

2. The air exchange rate was found to be insufficient to describe particle exchange rate as particle deposition rate, sizes and types should be taken into consideration.

3. The tracer-gas and particle decay curves were found to be simple exponential curves. Results indicated that well conditioned (i.e., uniform mixing) measurements were achieved since no scatter of data was observed.

ACKNOWLEDGEMENT

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REFERENCES

1. Turiel, I., "Indoor air quality and human health"' Stanford University Press, Stanford, California, 1985.

2. Farrance, K and Wilkinson, J. "Dusting down suspended particles", Building Services, 1990

3. Riffat, S.B. "Comparison of tracer-gas techniques for measuring airflow in a duct", J. Institute of Energy, Vol LXIII, 545, 1990, 18-21

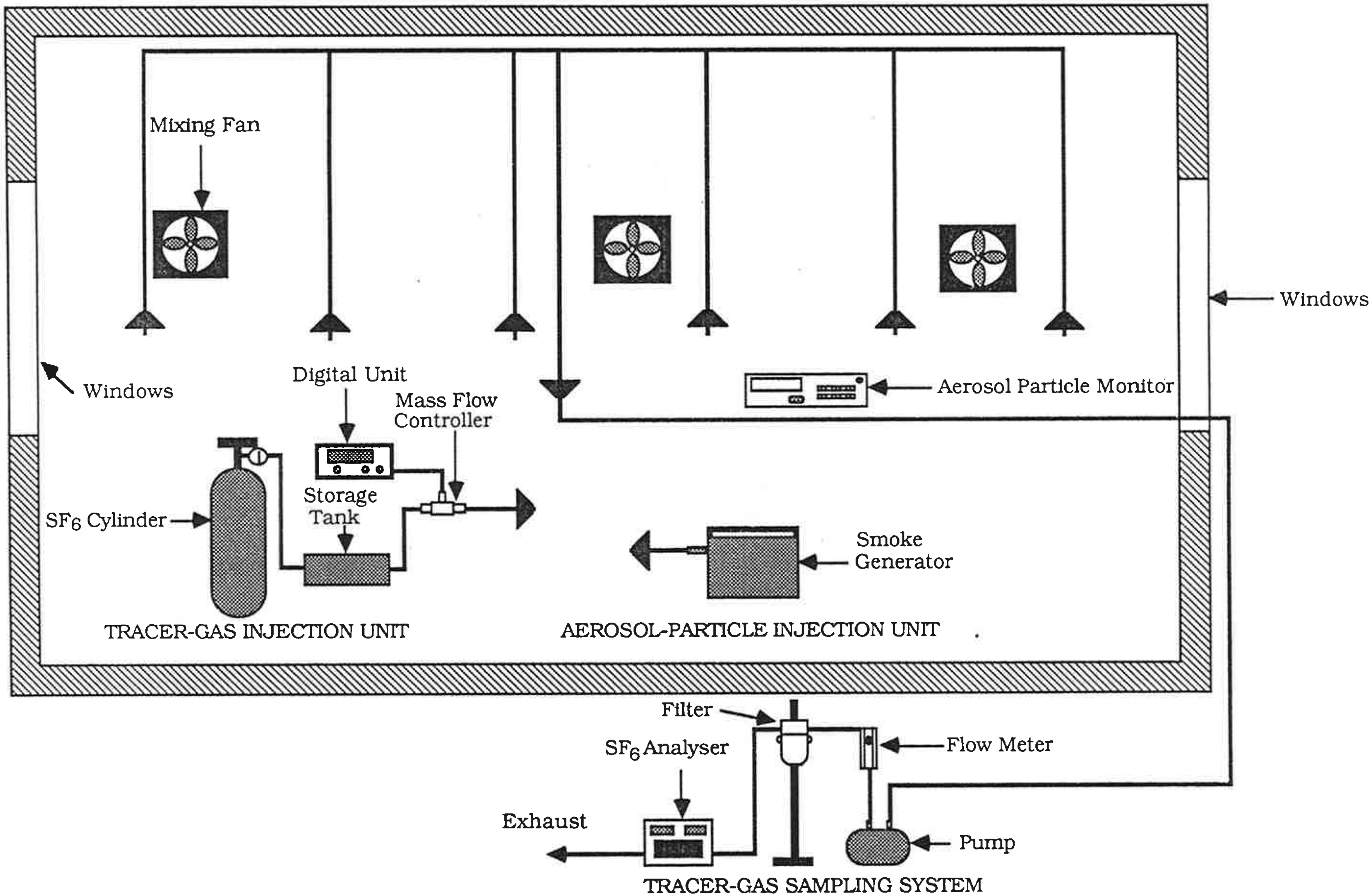

Figure 1 Schematic diagram of the single-zone system

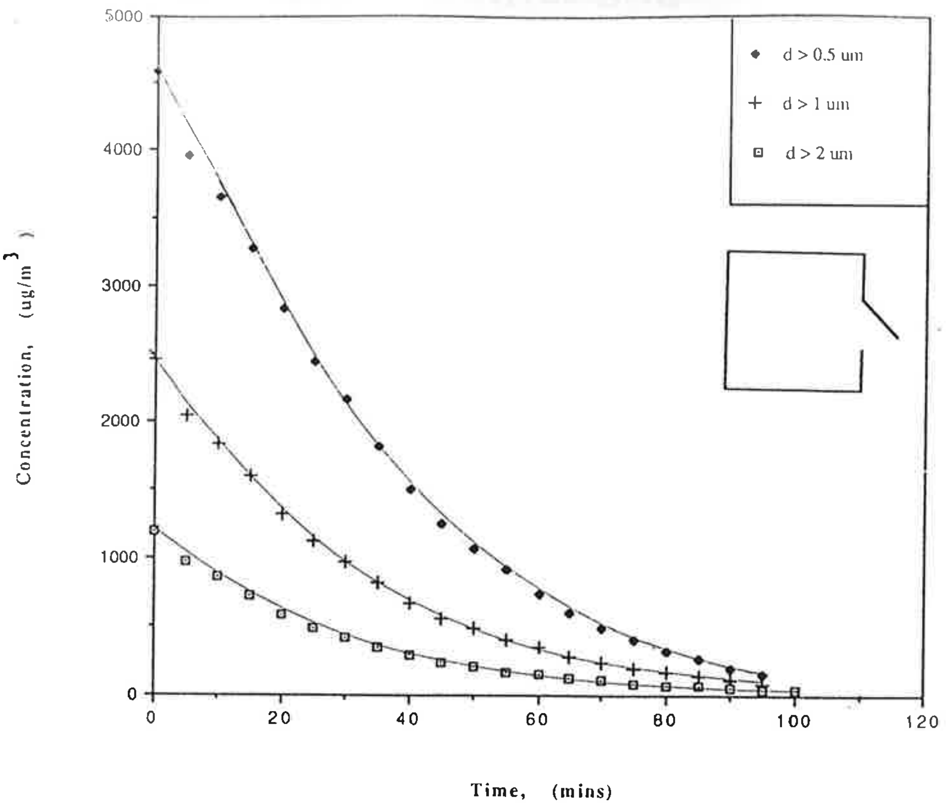

Figure 2 **Variation of particle concentration with time for one window half-open**

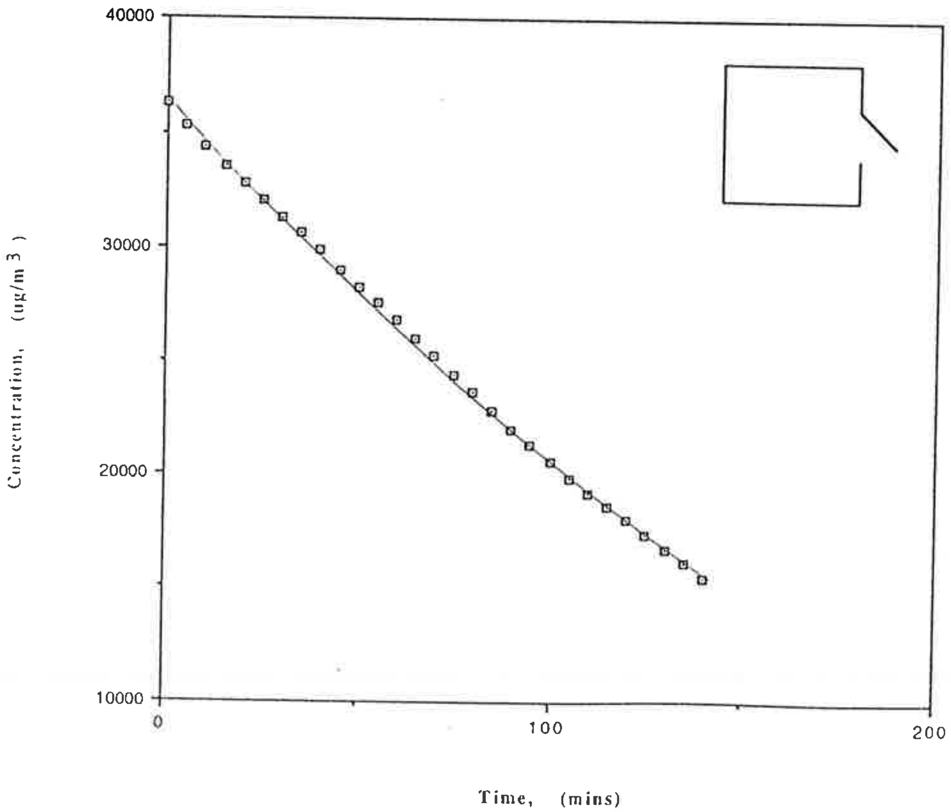

Figure 3 **Variation of tracer-gas concentration with time for one window half-open**

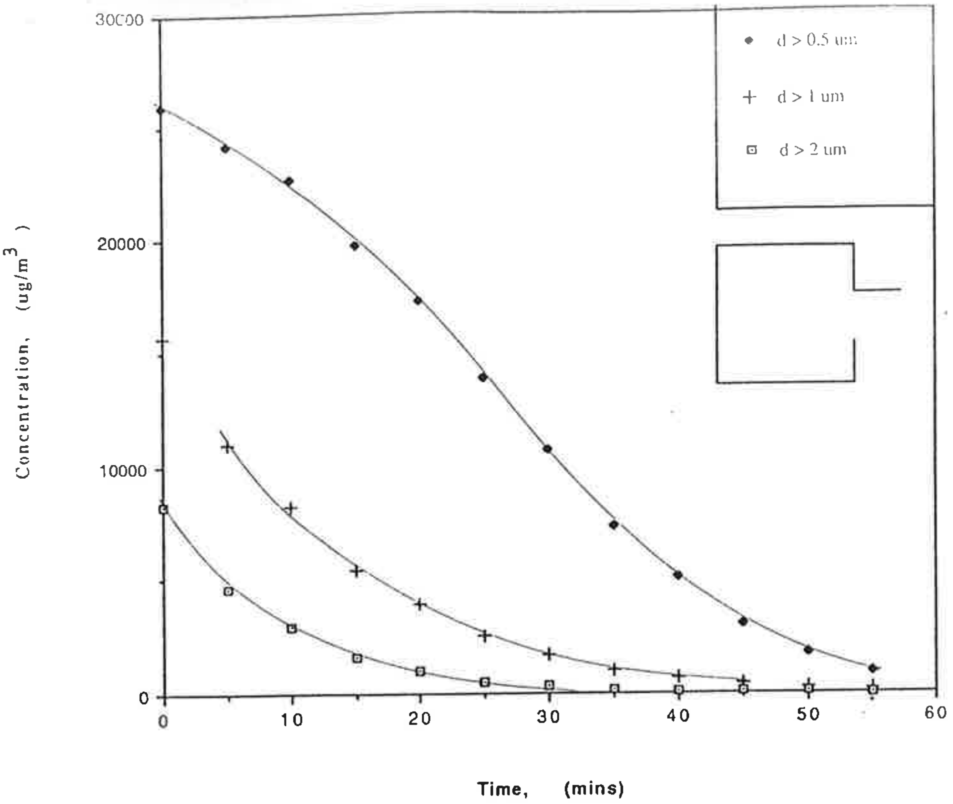

Figure 4 Variation of particle concentration with time for one window fully-open

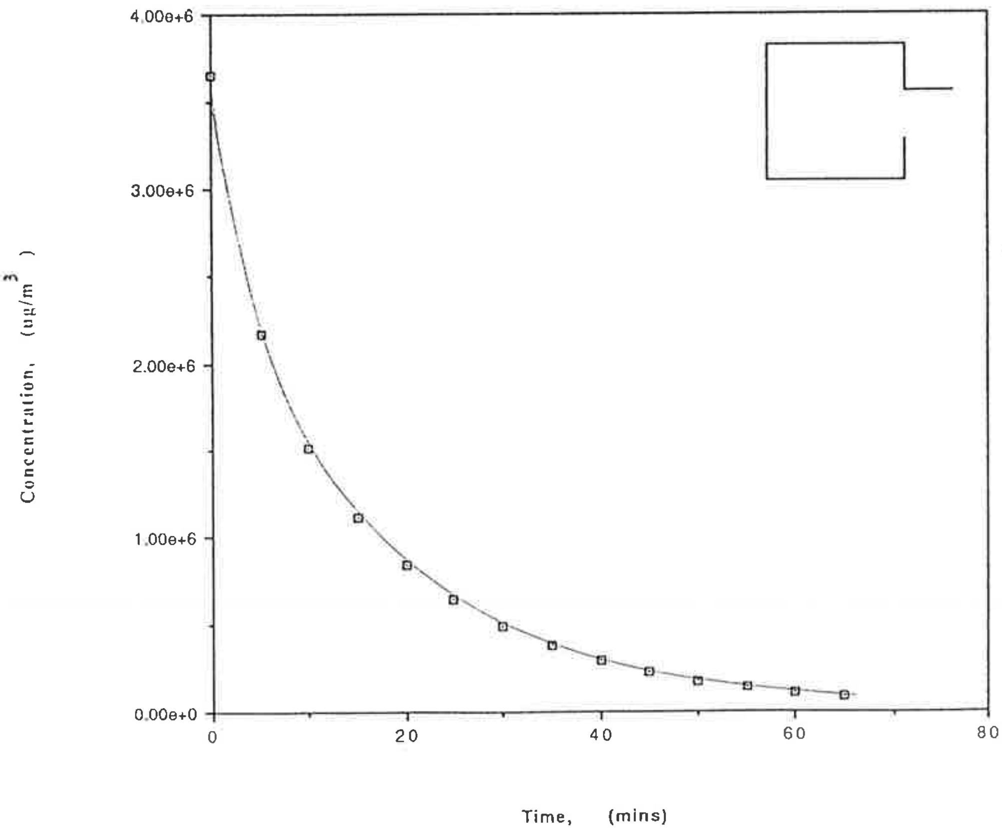

Figure 5 Variation of tracer-gas concentration with time for one window fully-open