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Short Communication

The Influence of Human Activity on the Vertical Distribution of Airborne Particle Concentration in Confined Environments: Preliminary Results

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Abstract Vertical concentration profiles for various size fractions of airborne particulate matter have been measured in a non-smoking indoor environment used mainly as a meeting point during coffee break (11.00 a.m.) and tea time (4.00 p.m.). This monitoring exercise was carried out using a novel sampling system specifically designed for measuring concentration gradients of airborne particles (but which can be easily modified for gaseous pollutants) over the first three metres from ground. The results show substantial gradients in concentration, with the highest occurring at around 1.3 m height. A plausible explanation for the measured time series of concentration at different levels from ground, and the vertical distribution of concentration, is thought to be human movement and activity in the confined environment. The implications that the results of this experiment have for indoor air quality standards for airborne particulate matter are discussed.

Key words Vertical concentration profiles; Suspended particulate monitoring; Human exposure; Air quality standards; Concentration gradients.

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Introduction

The association between airborne particle concentration and morbidity and mortality has been demonstrated by several epidemiological studies carried out in different parts of the world (see for example, COMEAP (1995)). As the majority of human beings tend to spend most of their time indoors, accurate knowledge of the concentrations to which they are exposed in this environment is essential, especially when setting up air quality standards.

Air quality standards, intended to protect public health, are based on human response to the pollutant in question for different exposures (an exposure for a person is calculated as the product of the pollutant concentration and time spent in the given environment). Knowledge of two factors is required in order to estimate integrated exposure (which is the sum of all the individual exposures associated with different environments). Firstly, the movements of the individual between different environments – this has usually been monitored by keeping a diary, or predicted with a stochastic model that simulates human activity patterns. Secondly, concentration data for these different environments – obtained from personal samplers or fixed monitors. However, fixed air monitoring stations observe air quality levels that are different from those that people come into contact with in their daily lives (Ott, 1980 and Vostal, 1994) and hence this method does not give a very realistic human exposure estimate. Personal monitors are carried by individuals close to breathing level and hence give a more realistic picture. In the case of airborne particles, personal monitors operate on the same principle as the high-volume sampler, i.e. air is drawn through a filter where particles are captured; weighing and pre-weighing of the filter gives the mass of the collected particulate matter which is used to estimate the average concentration during exposure provided that the volume of air passing the filter is known. The equipment is cumbersome

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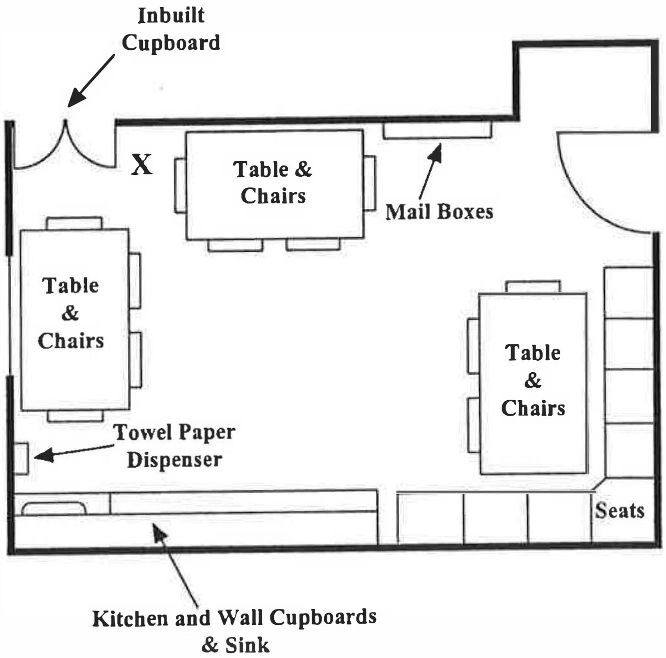

Fig. 1 Plan of the coffee room where vertical concentration profiles of airborne particulate matter were measured on 31 July and 1 August 1997. The exact location of sampling is denoted by an 'X'

and can only give the average concentration over a time period long enough to have a measurable mass of collected particles, which depends on the concentration being monitored and the airflow rate past the filter. Less cumbersome personal monitors, which utilise the electrostatic properties of airborne particles, are available (Brown et al., 1996 and Hemingway 1997) but have not yet been extensively evaluate as with the high-volume type, provide average v Hence while personal samplers monitor air wh inhaled by individuals, the resulting data have a temporal resolution.

The ideal situation is to monitor air quality monitors with high temporal resolution, at dif heights above ground in the different environn Micallef et al. (in press) developed the Kinetic Se tial Sampling (KSS) System which is an electror controlled sampling system for measuring air particle concentration at different pre-detern levels over the first three metres from ground. A summary of the operation of the KSS system is here.

Measuring Technique and Sampling Procedure

In the KSS system, a portable optical dust m (Model 1.104/5, Grimm Labortechnik Ltd., Ai Germany) is strapped to a "lift" which ascends descends, vertically at predetermined time inte The lift stops at six separate, but equally-spaced, for monitoring to take place. On completion of toring at the uppermost level, the lift returns di to the lower level before starting to ascend, lev level, once again. This sequence ensures that th for monitoring at each level is constant and th

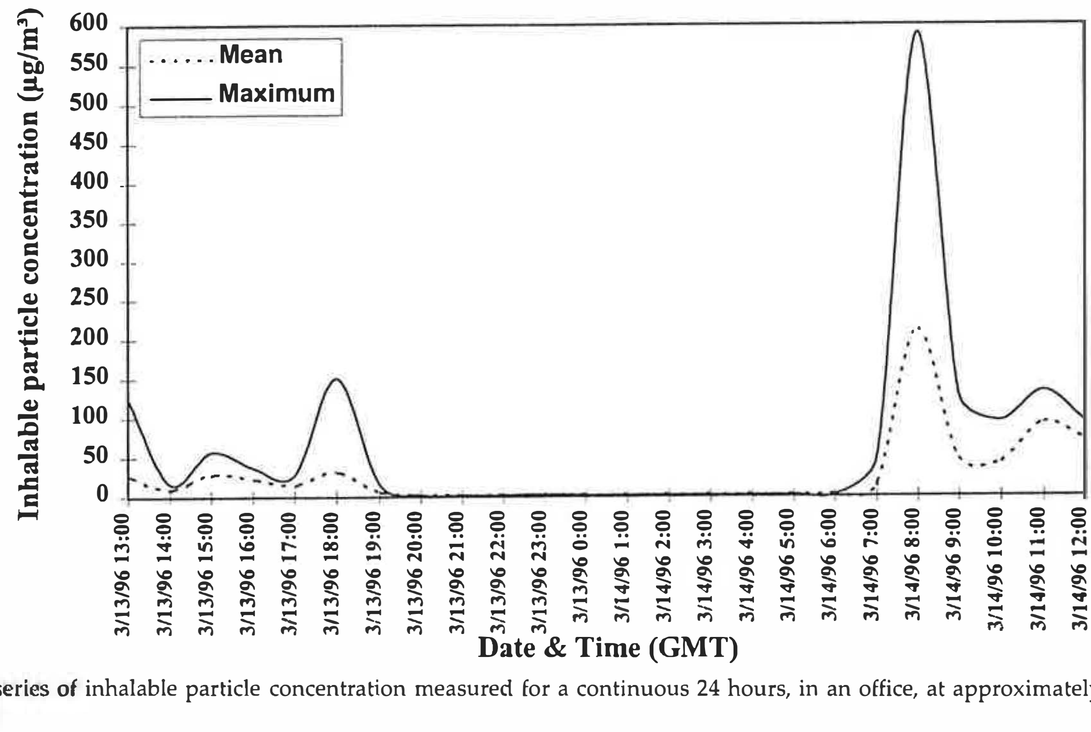

Fig. 2 Time series of inhalable particle concentration measured for a continuous 24 hours, in an office, at approximately 1.2 m from ground

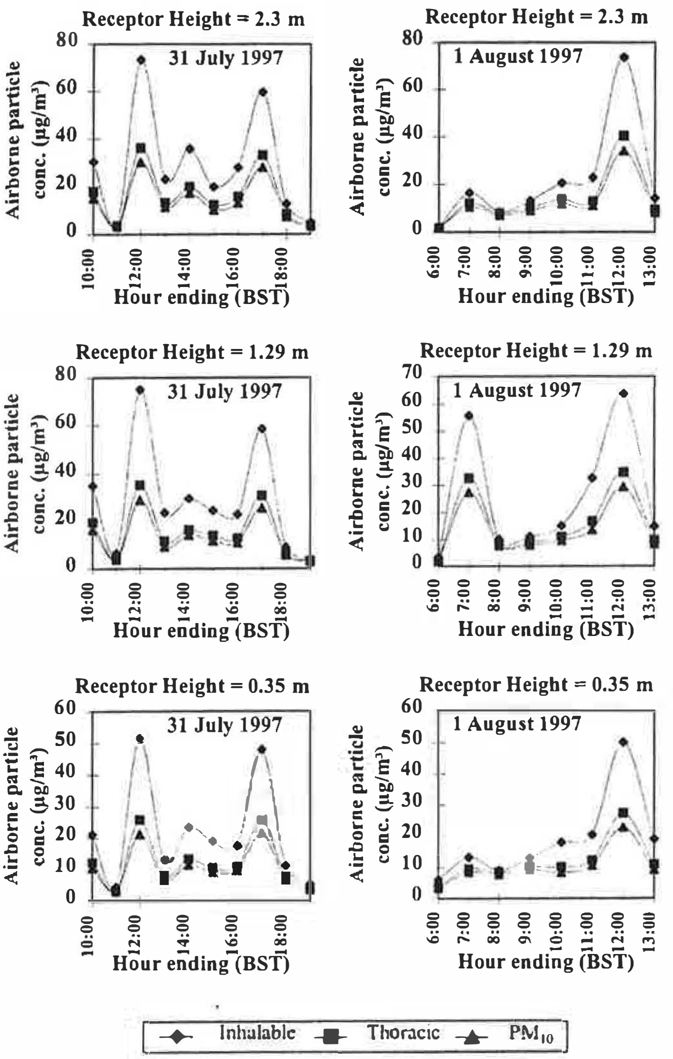

Fig. 3 Time series of inhalable, thoracic and PM_{10} fractions of airborne particulate matter measured in a coffee room (designated as a non-smoking environment) with a ground floor area of 16 m^2 and a height of 3.43 m, at heights 0.35, 1.29 and 2.30 m from ground

time interval between successive measurements at the same level is also identical. This feature is of great importance for comparison of successive data profiles. The whole operation is controlled by a purpose-built electronic circuit which was interfaced with the optical particle monitor in order to relate accumulated data to the appropriate receptor heights. In this work, the heights considered are 0.35, 0.81, 1.23, 1.77, 2.30 and 2.88 m above ground. Micallef et al. (in press) evaluated the KSS system in various indoor and outdoor environments and the validation exercise has shown that the interference of the sampling system with the spatial distribution of the concentration being measured is negligible. Data collected using the KSS system enable the plotting of vertical concentration profiles of various size fractions of airborne particulate matter. In this study the optical dust monitor used can detect particles with a diameter greater than or equal to 0.35 µm and has a cyclone sampling head fitted which allows particles with a diameter of around 15 µm to pass the inlet with 50% efficiency. The monitor was set to measure the inhalable (inspirable), thoracic and alveolic (respirable) fractions as defined by International Standard 7708 (International Organization for Standardization, 1994), as well as PM_{10} (which includes all particles which can pass through a size selective inlet with a 50% efficiency cut-off at 10 µm aerodynamic diameter) and $PM_{2.5}$ (defined as for PM_{10} but with a cut-off at 2.5 µm) airborne particle size fractions.

Measurements using the KSS system were carried out in a small room (c. 16 m^2) with a height of 3.43 m

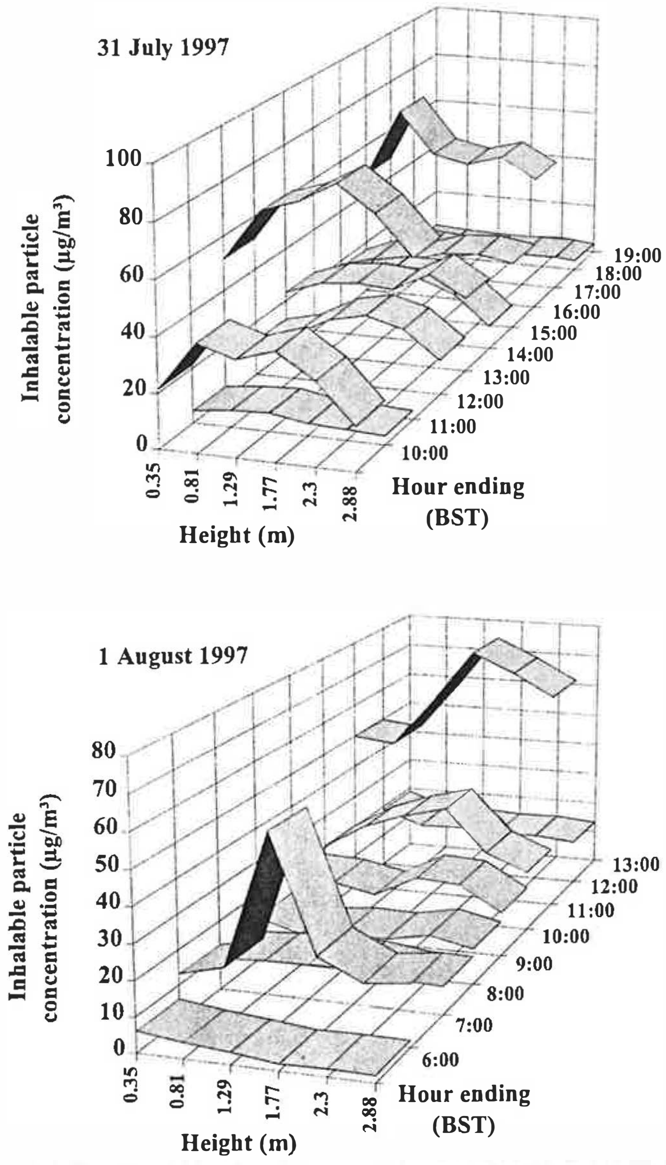

Fig. 4 Temporal development of vertical concentration profiles for inhalable particulate matter measured in a coffee room (designated as a non-smoking environment) with a ground floor area of 16 m^2 and a height of 3.43 m

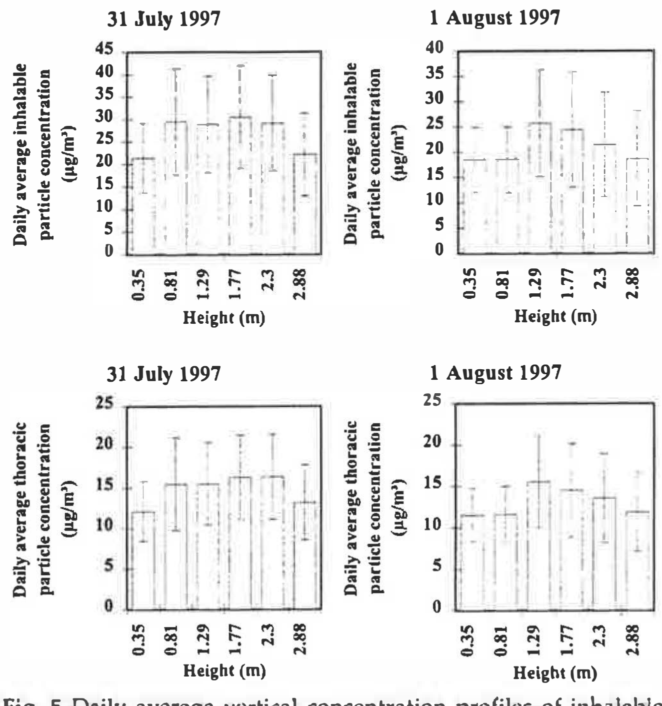

Fig. 5 Daily average vertical concentration profiles of inhalable and thoracic fractions of airborne particulate matter measured in a coffee room (designated as a non-smoking environment) with a ground floor area of 16 m^2 and a height of 3.43 m. The length of the "error-bars" is equal to one standard deviation of concentration at the given level

(Figure 1), used as a meeting point during coffee and tea breaks by members of staff of the Environmental Science Section. There is one door leading to the room, which was opened periodically during the time when it was occupied, and it has one large vertical sliding bay window, which was kept slightly open from the upper side during the experiment. The room is naturally ventilated and smoking is prohibited.

Prior to measurements made with the KSS system, a simple experiment was conducted in which the optical dust monitor was left running continuously for a 24-hour period in an office, situated in the same building as the coffee room described above. The office has a floor area of 18 m^2 and a height of 2.5 m. The monitor was placed on a large bench of an approximate height of 1 m, situated in the centre of the room. It was the results of this experiment which prompted further investigation.

A coffee room has been chosen for monitoring since such an environment is occupied only for a relatively short period of time (30–45 minutes); hence one can detect the effect of human activity on airborne particle concentration profiles without having to carry out prolonged monitoring before, after and during the event. This may lead one to question the effectiveness of the sampling system in capturing the effect of events which last for a time less than that required for completing a sampling cycle. One way of improving system is by decreasing the sampling time (at eac the levels) and/or the time the monitor takes to tr from one level to the next. Currently, the system i to record two or three measurements at each leve fore moving to the next sampling level. It can be s record one measurement, but this would generate few data. The speed of the platform carrying the monitor has to be small, otherwise the system i would start contributing to mixing and turbule This sets a lower limit on the time the monitor spe travelling between sampling levels. Hence, it is evi that the time needed for a complete cycle canno made as small as desirable. Furthermore, altho events such as walking by the instrument can b least an order of magnitude smaller in duration the minimum time needed for establishing one ver concentration profile, the "global" effect of the e takes longer. Hence the general effect of repeti events happening for a period of time comparabl one complete sampling cycle can be captured in data.

Results and Discussion

The time series of concentration of the inhalable ticle fraction for the 24-hour run, carried out in th

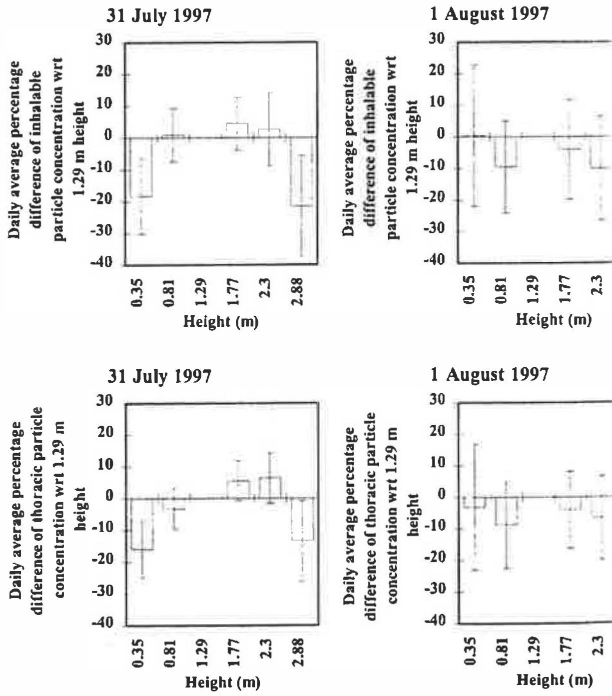

Fig. 6 Daily average percentage difference in inhalable and racic particle concentration calculated with respect to con tration measured at 1.29 m height. The length of the "error-b is equal to one standard deviation of the parameter at the g level

fice, is shown in Figure 2. Careful analysis of this graph has shown that its pattern correlates well with human movement and activity in the environment. The cycle started with a peak concentration at 3.00 p.m. (afternoon tea time) and gradually diminished when people returned to sedentary positions during normal working hours. The following peak at around 6.00 p.m. corresponded to the departure of the occupants. At night time, when the office was vacant and airborne particles settled and were deposited, concentration became negligible; the following morning there was a large increase in concentration which started at around 6.00 a.m. and levelled off at 9.00 a.m. The high concentration measured at this time is due to the cleaning activity carried out prior to the arrival of office personnel, which occurred between 9.00 and 10.00 a.m. It is interesting to note that both the maximum and average concentrations measured at this time were of the same order as that measured during departure at 6.00 p.m. the previous day. A secondary peak appeared at around 11.00 a.m. (coffee break).

This simple experiment clearly demonstrated the influence of human movement and activity on airborne particle concentration. Human movement tends to resuspend deposited particles from indoor surfaces and clothing, giving rise to an increased airborne concentration, but cleaning processes involving aerosol spraying, vacuum cleaning and floor polishing certainly tend to have a more pronounced effect.

Following this experiment, the KSS system was used to measure vertical particle concentration profiles in the coffee room. Time series of concentration of the inhalable, thoracic and PM_{10} fractions for this environment are shown in Figure 3 for three different heights. Sampling was carried out on two days (31 July and 1 August 1997) to address the question of reproducibility of the data. Once more, the time series reflected human activity in the room. On 31 July 1997, two major peaks were observed which coincided with coffee break (starting at 11.00 a.m.) and tea time (starting at 4.00 p.m.). The secondary peak appearing between 1.00 and 2.00 p.m. is associated both with some people collecting their mail before leaving for lunch and with others who have their lunch in the coffee room. On 1 August 1997, the early morning peak coincided with the arrival of the cleaning staff. After 8.00 a.m. the concentration steadily built up with the arrival of office personnel who collect their mail from the room. Maximum concentration was reached between 11.00 a.m. (start of coffee break) and 12.00 p.m. Temporal variation in concentration was similar for all levels except for the early morning peak which was much more pronounced at the 1.29 m height, coinciding roughly with the breathing level of a sedentary adult of average height.

Figure 4 shows the way in which the vertical concentration profile for the inhalable fraction changed with time. Two things can be noted, namely that human absence coincided with low concentrations at all levels from ground and that human activity induced higher concentration and concentration gradient with peaks appearing over the height range 1.29–1.77 m. This has implications for human health as it coincides with the average breathing level.

Figure 5 shows the average vertical profile for the inhalable and thoracic fractions. On average the highest concentration was measured at around 1.29 m. The length of the "error-bars" is equal to the standard deviation of concentration at the given level. It is evident that there was substantial variation in concentration, especially at the higher levels on 1 August 1997. This is thought to have been caused by a possible draught from the upper side of the window, causing local turbulence and fluctuations in concentration. In both profiles there was a step, for both days, between the 0.81 and 1.29 m heights, dividing the profiles into two parts having different characteristics. The lower parts exhibit lower concentrations with smaller variations as compared to the upper part of the profiles. The sampling system was standing close (approximately 0.3 m) away from a table of height 0.95 m, and this is thought to be the cause. It should be noted that although the large standard deviations in concentration may lead to a reduction in the significance of the difference between levels, this is not always the case as illustrated in Figure 6 (for 31 July 1997). Figure 6 shows the average percentage difference in concentration of the inhalable and thoracic fractions, with 1.29 m height taken as a reference. The highest concentrations were measured at heights of around 1.29 and 1.77 m.

The measurements presented suggest that different height groups of the population may be exposed to different concentrations in certain environments and that the extent to which human movement and activity influence the level and spatial distribution of airborne particles is not negligible. Further investigation into the problem is currently under way.

Acknowledgements

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