Indoor concentrations of $PM_{2.5}$ in day care centres

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Abstract

Exposure to particulate matter and in particular to fine particles ($PM_{2.5}$) has been linked to indices of respiratory morbidity and mortality.

In this pilot study we aimed to compare the indoor concentrations of particle pollution having an aerodynamic diameter of 2.5 µm or less ($PM_{2.5}$), between day care centres located in the Perth Metropolitan area and in the industrial area of Kwinana, Western Australia. A total of ten day care centres were monitored twice at the beginning and at the end of the sampling week.

According to the results, children who attended day care centres in Kwinana were exposed to higher levels of indoor and outdoor fine particles compared with those attending day care centres in Perth. The type of floor covering, presence of cooking facilities and age of the building were significantly associated with $PM_{2.5}$ concentrations. Children who live in industrial areas are exposed to higher concentrations of fine particles, which can be associated with adverse health effects.

Keywords: indoor air, day care centres, fine particles.

1 Introduction

A growing body of literature has demonstrated an association between particulate matter and daily morbidity or mortality changes. In fact particulate matter (PM) has been defined as one of the six criteria pollutants and the most important in terms of adverse effects on human health [1]. Particulate matter is defined as a mixture of solid particles and liquid droplets suspended in the air. These particles originate from a variety of sources, which include industrial processes, vehicle emissions, and environmental processes, which aid in the

WIT Transactions on Biomedicine and Health, Vol 14,
www.witpress.com, ISSN 1743-3525 (on-line)
doi:10.2495/EHR090021

transformation of the suspended solids. Most existing studies on air particulates have mainly used the total suspended particulate (TSP) or PM_{10}, which are particles less than 10 μm in aerodynamic diameter and called coarse particles. However, in recent years, scientific interest is now focusing more on the particle fraction that consists of more toxic components and is able to penetrate more deeply into lung airways, such as fine particles with size less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) and ultrafine particles ($PM_{0.1}$) with size less than 0.1 μm in aerodynamic diameter [2]. It is known that sulphuric acid aerosol, sulphate, and black smoke, all of which are found mainly in the fine fraction, are associated with short term health effects including respiratory symptoms.

Coarse particles are usually formed by industrial mechanical processes, agriculture and dusts from roads while the fine particles are often the result of secondary production and are by-products of industry, chemical reactions of other agents and industries. Other sources for these particles are biological, and include moulds, fungi and faecal matter from animals. $PM_{2.5}$ can be inhaled and exhaled easily and are rapidly absorbed through the alveoli tissues and transported throughout the body to target organs and tissues. These particles are of significance to health due to their potential for highly toxic substances to be rapidly transported through the body.

The aim of this study was to compare the indoor concentrations of $PM_{2.5}$ in day care centres located in Perth and in the industrial area of Kwinana and to identify the day care characteristics that might contribute to exposure levels of $PM_{2.5}$.

2 Methods

This pilot study was conducted during the winter period, August–September 2006, in child care centres located within the Perth Metropolitan area and Kwinana industrial area. Twelve day care centres were contacted and ten agreed to participate as five were located in Perth and the other five within the industrial area of Kwinana.

The monitoring was carried out over five weeks as the indoor measurements of $PM_{2.5}$ were undertaken twice, Monday and Friday, for the period of 24 hours. Indoor temperature and relative humidity were also recorded for the study period. Ambient concentrations for $PM_{2.5}$ and the records for ambient temperature and relative humidity were provided by the Department of Environment and Conservation, WA.

In addition to the indoor air quality measurements, certain characteristics of child care centres that might have an impact on indoor concentrations of air particles were also collected by using indoor air checklist. Information such as presence of air conditioner and cooking facilities, type of floor coverings and type of heating were recorded. Other important characteristics that were assessed were cleaning pattern (mornings or evenings), open windows, number of rooms and age of buildings.

2.1 Assessment of indoor exposure

Indoor concentrations of $PM_{2.5}$ were collected using the Model 8520 DustTrack Aerosol Monitor which is a real time monitor that provides continuous measurements of particles. The monitor works as air is drawn through a filter at flow rate 1.7 L/min. Only particles smaller than the cut-off size can pass through and all larger particles become trapped in a grit pot. The monitor provides reliable exposure assessment of particle concentrations with PM_{10}, $PM_{2.5}$ or $PM_{1.0}$ size fractions.

The physical parameters such as indoor temperature and humidity were measured for 24 hours by the Tinytag Data Logger which is a battery operated device. The available ranges of temperature measurements are between -40^0C and 75^0C. The operating range for the humidity logger is between 0% to 95%. The Tinytag data logger was pre-programmed to start and finish recording at specific times and to take measurements at certain time intervals.

2.2 Assessment of indoor exposure

Statistical analyses were performed with SPSS for Windows, version 18. All data was checked for normality and Non-parametric tests were applied if data did not follow normal distribution. Mann-Whitney test, Bivariate correlation and Pearson chi-square analysis were employed to explore differences and associations between variables. Linear Regression analysis was used to estimate the contribution that some variables may have on the indoor concentrations of $PM_{2.5}$. In all statistical analysis, two-tailed tests were used and a 5% level of significance was applied.

3 Results

Indoor $PM_{2.5}$ concentrations were measured in ten day care centres twice a week, at the beginning and at the end of the working week. The highest indoor and outdoor concentrations of $PM_{2.5}$ were measured in Kwinana industrial area with 83 $\mu m/m^3$ and 103.8 $\mu m/m^3$, respectively. (Fig1).

3.1 Indoor air quality in day care centres located in Kwinana and Perth

The statistical analysis showed higher indoor levels of $PM_{2.5}$ measured in Kwinana 13.8 $\mu m/m^3$ (1 $\mu m/m^3$ – 83 $\mu m/m^3$) when compared with those in Perth day care centres 11.6 $\mu m/m^3$ (0.1 $\mu m/m^3$ – 70 $\mu m/m^3$), Fig 1.

However, as can be seen from Fig 2, a higher proportion of children who attended day care centres in Perth were exposed to levels of $PM_{2.5}$ higher than the recently established WHO Guideline value of 25 $\mu m/m^3$, when compared with those attending the day care centres in Kwinana.

The ambient median concentration of $PM_{2.5}$ was significantly ($p<0.01$) higher in Kwinana industrial area with 25.6 $\mu m/m^3$ (2.4 $\mu m/m^3$ – 103.8 $\mu m/m^3$) when compared with 5.4 $\mu m/m^3$, (1$\mu m/m^3$ – 34.5 $\mu m/m^3$) recorded in Perth. Also, significantly more children who lived in Kwinana industrial area were exposed to higher than WHO Guideline value of 25 µm/m^3, when compared with the children who lived in Perth.

As mentioned earlier, measurements were undertaken twice a week, at the beginning and at the end of the week but no significant differences were established in indoor and ambient concentrations of $PM_{2.5}$ between the two recordings.

The statistical analysis showed that median temperatures recorded inside the day care centres in Perth were slightly higher (20^{0}C) than those measured in Kwinana (18.9^{0}C), Fig 4. The median ambient temperature was also higher in Perth when compared with those in Kwinana. With regard to relative humidity, higher indoor and outdoor levels were measured in Kwinana compared with Perth but no significant differences were established.

3.2 Characteristics of day care centres

All day care centres reported presence of air conditioning which was used for heating and cooling. Gas heaters were also reported in both locations, Kwinana and Perth, as a type of heating. No cooking facilities were available in the day care centres from Kwinana, while in Perth such facilities were present in three day care centres. Further to this, all day care centres in Perth were built more than 10 years ago, while in Kwinana the age of the buildings varied between

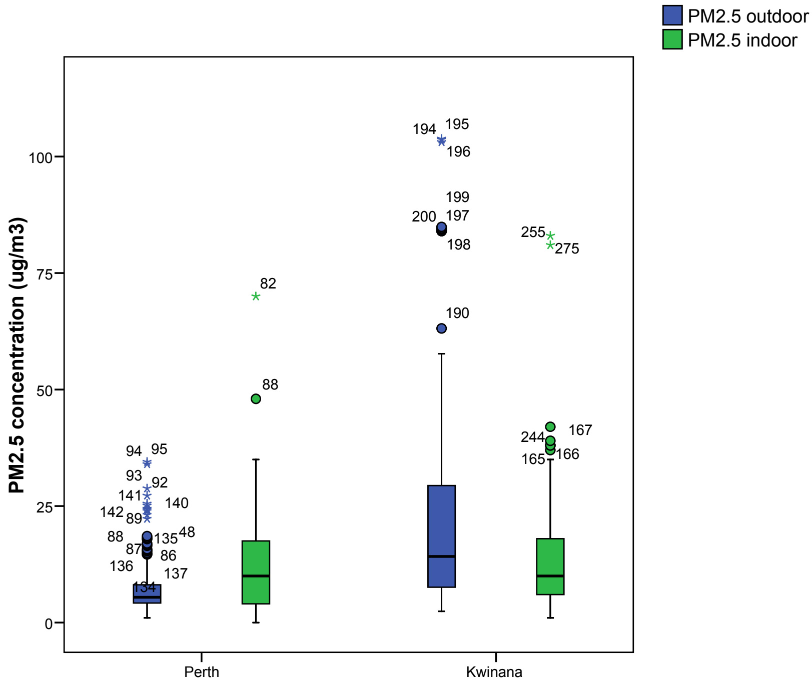

Figure 1: Median indoor and outdoor concentrations of $PM_{2.5}$ by location.

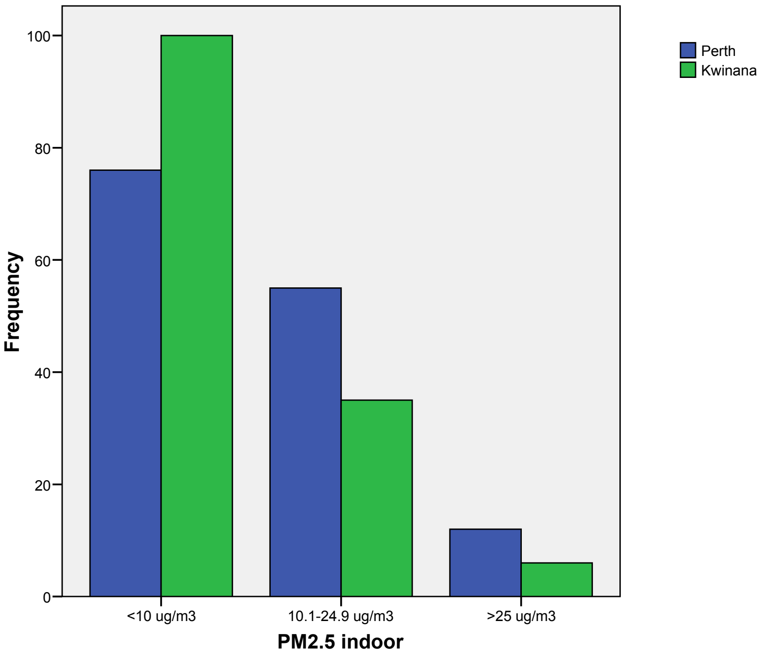

Figure 2: Frequency distribution of indoor $PM_{2.5}$ levels by location ($\mu m/m^3$).

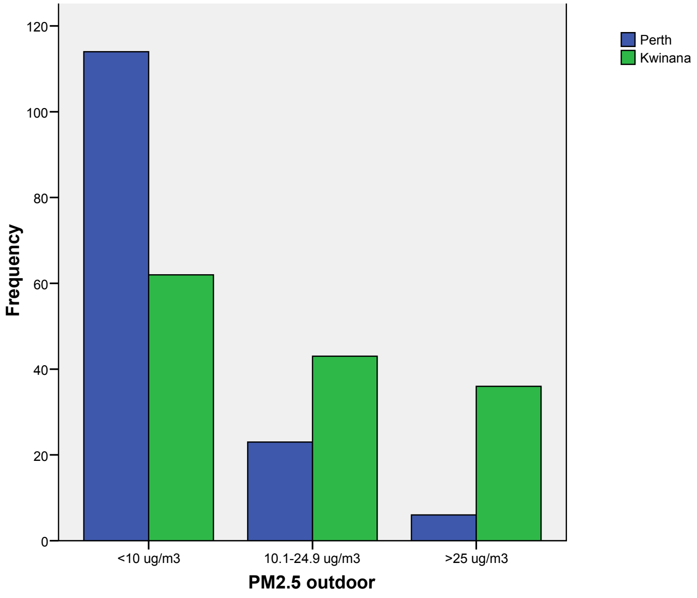

Figure 3: Frequency distribution of ambient $PM_{2.5}$ levels by location ($\mu m/m^3$).

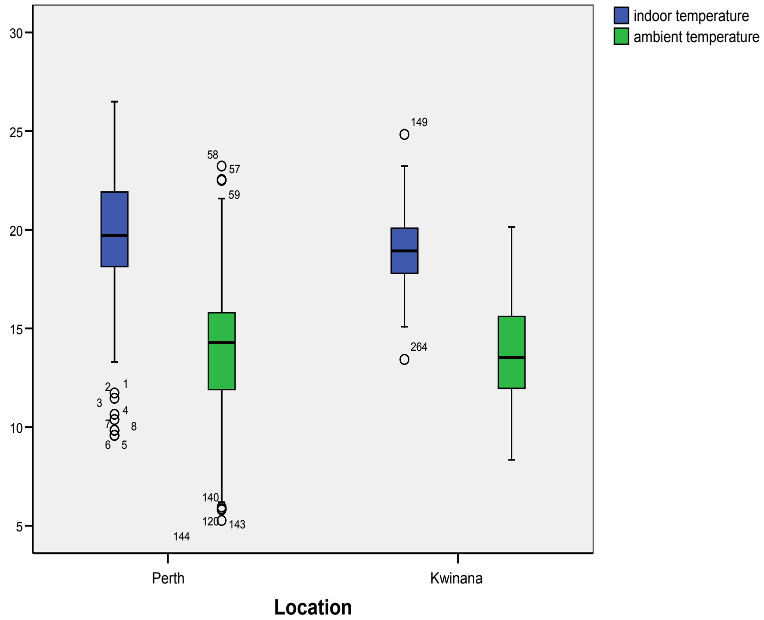

Figure 4: Temperatures (^{0}C) recorded in day care centres located in Perth and Kwinana.

5-10 years. Day care centres in the industrial area had their windows closed all day, which was in contrast to those in Perth where it was reported that windows were open almost every day for some period of time.

3.3 Contributing factors for indoor concentrations of $PM_{2.5}$

According to the Mann-Whitney test, significantly ($p<0.01$) higher $PM_{2.5}$ levels were recorded in day care centres with carpet and rugs when compared with those who used vinyl (Table 1). Having cooking facilities has also made a significant impact on $PM_{2.5}$ exposure levels as higher concentrations were measured in day care centres where cooking occurred every day (Table 1).

Significantly ($p<0.05$) higher mean indoor concentration of $PM_{2.5}$ were recorded in Perth day care centres when windows were kept closed all day with 14 µm/m^3, (range 4µm/m^3 – 35 µm/m^3) compared with days when windows were open 10.3 µm/m^3, (range 0.01 µm/m^3-70 µm/m^3). It appeared that day care centres in Kwinana kept the windows closed all day. Other characteristics that made significant influence on $PM_{2.5}$ concentrations were time of cleaning and presence of curtains (Table 1). It appears that having curtains in the day care centres and cleaning the centre in the morning significantly increase the indoor concentrations of fine particles.

According to the linear regression model, presence of carpet can increase the indoor $PM_{2.5}$ concentrations by 9 µm/m^3, while away from a busy road can

Table 1: Indoor concentrations of $PM_{2.5}$ in association with day care centre characteristics.

Child care characteristic	$PM_{2.5}$	Min $PM_{2.5}$	Max $PM_{2.5}$	p-value
Type of heating				
- gas	12.7	4	163	0.230
- AC	10.9	0.1	53	
Cooking				
- yes	12.5	1	153	0.002
- no	6.7	0.2	23	
Busy road				
- yes	13.0	0.1	153	0.071
- no	10.0	1.0	53	
Use of fans				
- yes	13.2	1	163	0.240
- no	10.8	0	153	
Number of rooms				
- one	9.8	1	70	0.09
- >2 or more	12.5	0.3	163	
Time of cleaning				
- morning	17.5	4.1	163	
- evening	8.4	0.1	83	0.002
Age of building				
- 5 -10 years	10.4	1	81	0.047
- >10 years	12.2	0.3	162	
Presence of curtains				
- yes	13.8	2	163	0.027
- no	7.2	0.2	83	
Floor covering				
- vinyl	8.6	0.1	81	0.002
- carpet & rugs	14.7	2	163	

reduce the indoor concentration of $PM_{2.5}$ by 3 $\mu m/m^3$. Having cooking facilities in the day care centre can increase particle concentrations by 1 $\mu m/m^3$.

4 Discussion

The indoor concentrations of $PM_{2.5}$ measured in this study were relatively low with the mean concentrations below the WHO Guideline value of 25 $\mu m/m^3$ [3] but comparable to the levels measured in European studies [4, 5]. Nevertheless, the study established a significant difference in exposure levels to particles indoors and outdoors between Kwinana and Perth metropolitan area. Children who attended day care centres in Kwinana appeared to be exposed to higher indoor and outdoor $PM_{2.5}$ compared to those recorded in Perth. Higher exposure levels of fine particles were observed also for day care centres near busy roads. This is in agreement with the results of a recent study conducted in China [6]. Further to this in Athens, Greece the contribution of road traffic to total $PM_{2.5}$ emission was estimated to be 66.5% while in Malaysia was 82% [7].

Day care characteristics may also contribute to the exposure levels of $PM_{2.5}$. Open windows were significantly associated with higher levels of fine particles which can be explained with increased dispersion of indoor $PM_{2.5}$ due to the increase of air exchange between indoor and outdoor air. Cooking facilities appear to also have an impact on $PM_{2.5}$ concentration. This is consistent with the findings reported by Wallace [8]. According to him, cooking activities is the second factor, after smoking that may have a significant influence on particle concentration.

In the present study, indoor temperature and relative humidity were measured to provide an indication for the thermal comfort in day care centres. Research shows that during winter the thermal comfort requires air temperature in a room to be between 20^0C and 24^0C and for relative humidity between 30% and 50%. In the current study the indoor temperature was recorded between 13^0C and 27^0C which according to Godish [9] can be associated with a range of respiratory symptoms including asthma. Indoor relative humidity ranged between 32% and 70%. Higher relative humidity levels, such as 70% have been associated with increased mite populations which can lead to increased allergy and irritation of respiratory tract. Further to this, combined effect of higher humidity and temperature may have significant effect on the level of formaldehyde in an indoor environment which can be associated with irritation of the respiratory tract, asthma and are carcinogenic in high concentrations [9].

5 Conclusion

Despite the low levels of particles measured in this study, a significant difference in $PM_{2.5}$ concentrations was established between day centres as children from Kwinana industrial area, appeared to be exposed to higher levels which can be associated with increased prevalence of respiratory illnesses. A more detailed study is required to investigate the association between respiratory illness among children and indoor air quality in day centres.

References

[1] WHO. Air Quality Guidelines for Europe. 2nd Edition: WHO 2000.
[2] Villeneuve PJ, Golberg MS, et al. Fine particulate air pollution and all-cause mortality within the Harvard six-cities study: variations in risk by period of exposure. AEP 2002; 12(8): 568-576.
[3] WHO. WHO air quality guidelines global update 2005.
[4] S Johannesson, K Bergemalm-Rynell, et al. Indoor concentrations of fine particles and particle-bound PAHs in Gothenburg, Sweden. Journal of Physics: Conference Series 2009; 151: 1-6.

[5] Koistinen KJ, Hanninen O, Rotko T, at al. 2001. Behavioural and environmental determinants of personal exposure to PM2.5 in EXPOLIS-Helsinki, Finland. Atmospheric Environment 2001; 35(14):2473-81.
[6] Hong Huang, Shun-cheng Lee, et al. Characteristics of indoor/outdoor PM2.5 and elemental components in generic urban, roadside and industrial areas of Guangzhou City, China. J Environmental Science 2007; 19:35-43.
[7] Xianglu Han, Luke Naeher. A review of traffic related air pollution exposure assessment studies in the developing world. Environment International 2006; 32:106-120.
[8] Wallace L. Real-Time Monitoring of Particles, PAH, and CO in an Occupied Townhouse. Applied Occupational and Environmental Hygiene. 2000; 15(1):39-47.
[9] That Godish. Air Quality. Edition 4, CRC Press, 2003.