Abstract

Issue addressed: There are moves to ban smoking in outdoor areas of pubs, restaurants and cafes. Some argue that this is unnecessary as exposure to second hand smoke (SHS) is minimal. The aim of this study was to determine potential exposure of patrons to SHS in outdoor areas of eating and drinking venues.

Methods: Concentrations of fine particulate matter (PM$_{2.5}$) were measured in the alfresco areas of 28 cafes and pubs. Data were collected on the number of smokers present during sampling and factors that could influence PM$_{2.5}$ concentrations. PM$_{2.5}$ concentrations for periods with and without smokers were compared using paired and independent sample tests.

Results: PM$_{2.5}$ concentrations were significantly increased when there was at least one smoker compared to periods with no smoking (14.25 µg/m$^3$ and 3.98 µg/m$^3$, respectively). There was evidence of a dose response increase with mean concentrations for none, one and two or more smokers of 3.98, 10.59 and 17.00 µg/m$^3$, respectively. The differences remained significant after controlling for other factors. When two or more people were smoking, average PM$_{2.5}$ reached levels the US Environmental Protection Agency warns may put particularly sensitive people at risk of respiratory symptoms.

Conclusions: Smoking increases PM$_{2.5}$ concentrations in outdoor areas to levels that are potentially hazardous to health.

Key words: Tobacco, smoking, advocacy, public health, legislation.

So What

The study demonstrates that in outdoor well-ventilated areas, SHS levels can be high enough to be a health risk to others nearby. This supports the concept of banning smoking in outdoor eating and drinking venues where people may spend extended periods of time.
premises and restaurants; however, the restrictions do not apply to open areas of hospitality venues. In most states of Australia non-smokers are still exposed to SHS in the alfresco areas of many hospitality venues and other public places.

To address this in WA, the Tobacco Products Control Amendments Bill 2008 was introduced to WA Parliament in November 2008, and passed in October 2009. The Bill legislates for a ban on smoking in alfresco dining and outdoor areas of pubs and clubs, in private cars when children are present, and in other specified public places. Outdoor smoke free legislation has been implemented in other Australian states to various degrees in relation to alfresco eating and drinking areas, beaches, sports facilities, building entrances and playgrounds. Some opponents of action on SHS have argued that smoking bans may be unnecessary in outdoor areas where people are not unavoidably in close proximity for lengths of time. However, the limited number of studies on outdoor SHS have suggested that tobacco smoke concentrations in outdoor areas may be as high as SHS indoors, particularly during smoking and in close range to smokers. In contrast to indoor smoking however, SHS dissipates soon after smoking ceases outdoors. The concentration of outdoor SHS is a product of the density and distribution of smokers, wind direction and speed, and the stability of the atmosphere. High outdoor SHS concentrations are generated by high smoker density, low wind velocities and stable atmospheric conditions.

Repace and Rupprecht measured respirable particle pollution in five alfresco cafes in Helsinki and found air pollution levels between five and 20 times that of sidewalks of traffic filled streets. Studies have recorded substantial variation in SHS exposure outdoors as a function of the number of cigarettes smoked, the position of the air quality measuring device relative to smokers and atmospheric conditions. This study aimed to demonstrate the potential for SHS exposure in alfresco eating and drinking areas of WA cafes and pubs, where smoking restrictions had not yet been brought into effect.

Methods

Venues

A selection of cafes and pubs where smoking was permitted in outdoor seating areas were visited between December 2008 and February 2009. Testing was conducted at 12 cafes and 16 pubs located in eight local government areas in metropolitan Perth and Mandurah.

Procedure

Particulate matter with an aerodynamic diameter of \( \leq 2.5 \) microns (PM\(_{2.5}\)) was measured using the SidePak AM510 air monitor produced by TSI Incorporated, Minnesota USA (‘SidePak’). A minimum of 15 minutes of PM\(_{2.5}\) measurements were collected in the outdoor area of each venue while smokers were present. During each sampling period, the tester completed a venue survey (detailed below) and recorded the time when each smoker lit up and, where possible, when they stopped smoking.

The SidePak inlet was fitted with the PM\(_{2.5}\) impactor because all tobacco smoke particles are within that size range and particulates of that size are released by burning tobacco in large quantities. PM\(_{2.5}\) is therefore considered a suitable marker for SHS. A calibration factor of 0.32 was applied to the raw data as is suitable for SHS. The SidePak was zero-calibrated every three weeks during the testing period. The SidePak was positioned in a handbag with just the end of the intake tube sticking out to collect the air. The handbag was positioned over the tester’s shoulder or on a seat; as close to breathing space as possible while remaining inconspicuous so as not to interfere with normal behaviour. The SidePak was set to record PM\(_{2.5}\) readings at one minute intervals for the duration of the test.

Information about each venue was recorded at the time of testing. Data were collected on the type of venue (pub or café), characteristics of the outdoor area (size, level of enclosure, location of indoor entrances), location (on a main road, side street or courtyard), patron information (maximum and average number of patrons, maximum and average number of people smoking), pedestrian and road traffic (four-point scale ranging from no traffic to very busy) and atmosphere characteristics (level of wind, cloud cover, rain and temperature).

Statistical analyses

Test data were downloaded from the SidePak to SPSS Version 17 for analysis. The one minute logging intervals produced one data point for each minute of testing. The SidePak gives readings of milligrams of particles per cubic metre of air. Recorded readings were converted to micrograms per cubic metre of air (µg/m\(^3\)). The venue survey information was also entered into SPSS.

The data were coded in two ways. Initially, each minute of data was coded as ‘smoker present’ (coded as 1) or ‘no smoking’ (coded as 0). The ‘smoker present’ code was given from the closest minute to when a smoker was recorded as having lit up, as recorded on the venue survey. If the time the smoker finished smoking was recorded, the data were coded as ‘no smoking’ from the next minute. If this was not
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recorded, a cigarette was assumed to take four minutes to smoke from lighting up to butting out. This was based on an average smoking time of 4.15 minutes from research conducted through the University of Western Australia School of Paediatrics and Child Health (Devadason S, 2009, personal communication, February 11). Second, the data were re-coded as ‘no smoking’, ‘one smoker’ or ‘two or more smokers’ to determine if there was a dose-response relationship for PM$_{2.5}$ with the number of smokers.

The PM$_{2.5}$ concentrations were not normally distributed and could not be transformed to achieve a normal distribution. Therefore, nonparametric tests were conducted. These tests included a Mann-Whitney U test to compare the mean PM$_{2.5}$ level for periods with ‘smoker present’ with all ‘no-smoking’ periods across all venues. A Wilcoxon Signed Ranks test was used with paired data to compare smoking and non-smoking periods at the same venue. This was to ensure results would not be strongly influenced by a large difference at just one venue. To investigate if there was a dose-response relationship depending on the number of smokers, the data were grouped into three categories, ‘no-smoking’, ‘one smoker only’ and ‘two or more smokers’, and analysed using a Kruskal-Wallis test. Multiple linear regression models were then constructed to determine if smoking affected PM$_{2.5}$ concentrations controlling for other factors. For the regression analyses PM$_{2.5}$ concentrations were log transformed as the residuals were normally distributed using the transformed, but not raw, data. The variables included in the models were the number of smokers (zero, one, and two or more), average number of patrons, roof covering (no cover, overhead only, overhead and side covering), type of street the venue was located on (busy main road, busy suburban road, quiet street, pedestrian traffic only), level of road traffic and wind level (very windy, moderately windy, light winds or calm). Data were entered using a Stepwise variable entry method. Variables remained in the model if they were significantly associated with the dependent variable (PM$_{2.5}$ concentration) at the 0.05 level.

Results

Across the 28 venues, 157 non-smoking minutes and 388 smoking minutes were logged. An average of 19.46 minutes of data were collected from each venue (range = 14 to 28 minutes). Descriptive statistics of the PM$_{2.5}$ concentrations were calculated and are summarised in Figure 1. Mean PM$_{2.5}$ concentrations for no smokers, one only, one or more and two or more smokers were 3.98, 10.59, 14.25 and 17.00 µg/m$^3$ respectively. The highest recorded level of PM$_{2.5}$ was 142.08 µg/m$^3$.

At 27 of the venues visited, 10 or fewer people were observed to smoke during the testing periods. At 21 of these venues, five or fewer people were observed to smoke during the testing period. At least one smoker was present at every venue visited. Particulate concentrations were statistically significantly higher during the ‘smoker present’ periods (median=8.32 µg/m$^3$) compared to the ‘no smoking’ periods (median=2.56 µg/m$^3$, $p<0.001$) when all venues were included.

Figure 1: Boxplot of descriptive statistics of PM$_{2.5}$ (µg/m$^3$) categorised by the number of active smokers present.

Note. The median is represented by the line in the box, while box limits represent 25th and 75th percentiles. The whiskers extend to 10th and 90th percentiles. Values above the 90th percentile and below the 10th percentile are plotted separately.
Twenty-two venues were included in the paired analysis. Six venues did not have any non-smoking minutes and were therefore excluded from this analysis. For these venues, there were 279 ‘smoker present’ minutes and 157 ‘no smoking’ periods. For these venues there was still a statistically significant difference in PM$_{2.5}$ level between the average ‘smoker present’ (median=5.44 µg/m$^3$) and ‘no-smoking’ minutes (median=2.56 µg/m$^3$, p<0.001).

The amount of time with no, one and two or more smokers were 157, 156 and 224 minutes, respectively. Data from eight minutes of testing were excluded from analyses as it was unclear how many smokers were present. There were statistically significant differences in PM$_{2.5}$ level when no, one and two or more smokers were present (p<0.001; see Figure 1).

Multiple linear regression models were constructed. The model containing all the variables predicted 40.7% of the variance in PM$_{2.5}$ level (F(4,532)=41.406, p<0.001). A summary of the model is provided in Table 1. After controlling for the other variables, the number of smokers (zero, one, or two or more) remained a significant predictor of PM$_{2.5}$ level, explaining 24.3% of the variance in PM$_{2.5}$ level. In the model there was evidence of a significant dose-response relationship with significant increases in PM$_{2.5}$ concentrations with the number of smokers. The number of smokers was the greatest contributor of all the modelled variables in explaining the variance in PM$_{2.5}$ level. Other factors that significantly contributed to PM$_{2.5}$ concentrations included wind level, outdoor cover, average number of patrons, street type and road traffic. As expected PM$_{2.5}$ decreased in windier conditions, increased when the covering increased, and increased with the number of patrons, on busy roads and with the amount of traffic (Table 1).

**Discussion**

This study demonstrated that smoking in outdoor venues can significantly increase airborne PM$_{2.5}$ levels. Increased PM$_{2.5}$ concentrations were observed when there was at least one smoker at an outdoor venue. Concentrations were further increased when there were two or more smokers, providing stronger evidence that the main source of the PM$_{2.5}$ was from the cigarettes. Finally, when other factors that could impact on ambient PM$_{2.5}$ concentrations were controlled, such as traffic and meteorological conditions, the number of smokers remained a significant contributor to the increased PM$_{2.5}$ levels.

The average PM$_{2.5}$ concentration in this study recorded over venues with one or more smokers (14.25 µg/m$^3$) was lower than the 27.3 µg/m$^3$ average recorded while cigarettes were actively smoked in 69 outdoor dining areas in Melbourne,$^{19}$ the 36 µg/m$^3$ average recorded over four outdoor smoking areas in Wellington, New Zealand,$^{25}$ and the 96 µg/m$^3$ average recorded over 20 outdoor smoking areas in Canada.$^{20}$

The peak concentration recorded in the study (142.08 µg/m$^3$) was lower than the maximum recorded in the outdoor dining areas in Melbourne (483.9 µg/m$^3$)$^{19}$ and considerably lower than the maximum recorded in the Canadian study (1318 µg/m$^3$)$^{20}$ Consistent with previous studies,$^{19,20}$ peak PM$_{2.5}$ concentrations in the study are much higher than average concentrations over testing periods.

Differences in PM$_{2.5}$ concentrations potentially result from variation in the degree of venue enclosure and situational variability in the number of active smokers, smokers’ distance from the SidePak and other factors including level of wind. Degree of venue enclosure is particularly relevant in interpreting differences with the Canadian study where 15 of 20 venues had 100% roof covering and 16 of 20 venues had

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE B</th>
<th>t</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.821</td>
<td>0.212</td>
<td>18.029</td>
<td>3.405–4.237</td>
</tr>
<tr>
<td>No. smokers = 0</td>
<td>-0.872</td>
<td>0.092</td>
<td>-9.502</td>
<td>-1.052–0.692</td>
</tr>
<tr>
<td>No smokers = 1</td>
<td>-0.217</td>
<td>0.091</td>
<td>-2.375</td>
<td>-0.396–0.037</td>
</tr>
<tr>
<td>Number of smokers ≥ two</td>
<td>0a</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Street type (busy main road)</td>
<td>0.969</td>
<td>0.198</td>
<td>4.899</td>
<td>0.581–1.358</td>
</tr>
<tr>
<td>Street type (busy street)</td>
<td>0.890</td>
<td>0.151</td>
<td>5.904</td>
<td>0.594–1.186</td>
</tr>
<tr>
<td>Street type (quiet street)</td>
<td>0.395</td>
<td>0.173</td>
<td>2.284</td>
<td>0.053–0.734</td>
</tr>
<tr>
<td>Street type (other)</td>
<td>0a</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Outdoor cover (fully open)</td>
<td>-0.649</td>
<td>0.196</td>
<td>-3.308</td>
<td>-1.035–0.624</td>
</tr>
<tr>
<td>Outdoor cover (overhead cover only)</td>
<td>-0.529</td>
<td>0.210</td>
<td>-2.524</td>
<td>-0.941–0.117</td>
</tr>
<tr>
<td>Outdoor cover (overhead cover and enclosed sides)</td>
<td>0a</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Road traffic (very busy)</td>
<td>-0.955</td>
<td>0.259</td>
<td>-3.684</td>
<td>-1.464–0.446</td>
</tr>
<tr>
<td>Road traffic (moderately busy)</td>
<td>-0.372</td>
<td>0.122</td>
<td>-3.061</td>
<td>-0.611–0.013</td>
</tr>
<tr>
<td>Road traffic (quiet)</td>
<td>-0.278</td>
<td>0.133</td>
<td>-2.085</td>
<td>-0.539–0.016</td>
</tr>
<tr>
<td>Road traffic (no road traffic)</td>
<td>0a</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Wind level (moderately windy)</td>
<td>-0.872</td>
<td>0.308</td>
<td>-2.830</td>
<td>-1.478–0.267</td>
</tr>
<tr>
<td>Wind level (light breeze)</td>
<td>-0.612</td>
<td>0.215</td>
<td>-2.850</td>
<td>-1.034–0.190</td>
</tr>
<tr>
<td>Wind level (calm)</td>
<td>0a</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Average crowd size</td>
<td>0.007</td>
<td>0.003</td>
<td>2.344</td>
<td>0.001–0.014</td>
</tr>
</tbody>
</table>

Note: a) This parameter is set to zero because it is redundant.
at least 80% wall covering. These physical characteristics reflect the colder climate and contribute to higher SHS exposure levels. The extent of enclosure of the venue was associated with PM$_{2.5}$ levels in this study. Most venues had no or only overhead cover with only 7% of venues having both overhead and side cover.

The Canadian study and our findings of increased PM$_{2.5}$ with greater enclosure demonstrate the potential limitations of regulations that allow a broad definition of outdoor areas, such as in NSW and Victoria. Although testing would have to be conducted in those jurisdictions to account for different meteorological conditions, it is likely that venues that provide the minimum exposed area, under the existing regulations, may not be providing sufficient protection for patrons.

Smoking bans in some outdoor areas, such as sports stadia, where people are seated in close proximity for lengths of time, receive little criticism. However, critics of outdoor smoking regulation cite various arguments against bans extending to other outdoor settings: a thin evidence base, the claimed triviality of generally very brief exposures to others’ smoke, the paternalistic nature of a zero tolerance approach, and the inappropriateness of public health justifications for matters of community preference.

Proponents of outdoor smoking bans argue that further bans will reduce the modelling of smoking to children and therefore smoking initiation, assist quit attempts and prevent acute and chronic health effects. Alfresco areas of hospitality venues are popular in Australia, but are often concentrated with smokers as an unintended effect of indoor smoking bans. This study has demonstrated that in busy alfresco areas with numerous smokers present, non-smokers may be exposed to a considerable amount of SHS.

The data also suggest a dose-response relationship with PM$_{2.5}$ increasing with the number of smokers. These results are of concern as testing was conducted during the day and often during working hours, which are likely to be less busy times for many of the venues selected. It is likely, therefore, that PM$_{2.5}$ levels will be much higher where more smokers were present. This may be particularly relevant for outdoor areas of hotels and pubs during peak periods, as smoking is prohibited in indoor areas in most jurisdictions. Apart from exposure of patrons who are sitting outside, people will continue to be exposed indoors as SHS can enter indoor spaces through open doors or windows, especially in warm periods when doors and windows may be left open.

There are no guidelines or standards presently available for short term exposure to PM$_{2.5}$. Australia’s National Air Quality Standards (NAQS) set an advisory reporting standard for PM$_{2.5}$ of 25 µg/m$^3$ over a one day period. The NAQS reporting standard is consistent with the World Health Organization guidelines for 24-hour mean PM$_{2.5}$ levels. The Air Quality Index produced by the US Environmental Protection Agency (EPA) indicates the level of risk associated with increasing PM$_{2.5}$ concentrations, as outlined in Table 2. These guides were used to assist interpretation of the results of the current study.

Table 2: US Environmental Protection Agency Air Quality Index.

<table>
<thead>
<tr>
<th>Air Quality</th>
<th>PM$_{2.5}$ (µg/m$^3$)</th>
<th>Health Advisory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>≤15</td>
<td>None</td>
</tr>
<tr>
<td>Moderate</td>
<td>16–40</td>
<td>Unusually sensitive people should consider reducing prolonged or heavy exertion.</td>
</tr>
<tr>
<td>Unhealthy for Sensitive Groups</td>
<td>41–65</td>
<td>People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.</td>
</tr>
<tr>
<td>Unhealthy</td>
<td>66–150</td>
<td>People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion. Everyone else should reduce prolonged or heavy exertion.</td>
</tr>
<tr>
<td>Very Unhealthy</td>
<td>151–250</td>
<td>People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.</td>
</tr>
<tr>
<td>Hazardous</td>
<td>≥251</td>
<td>People with heart or lung disease, older adults, and children should remain indoors and keep activity levels low. Everyone else should avoid all physical activity outdoors.</td>
</tr>
</tbody>
</table>

When no smokers or just one smoker was present, the average levels of PM$_{2.5}$ were within the ‘good’ range of the US EPA Air Quality Index. When two or more people were smoking in the alfresco area, the average level of PM$_{2.5}$ was significantly higher at 17.00 µg/m$^3$. The US EPA warns that PM$_{2.5}$ at this level may put particularly sensitive people at risk of respiratory symptoms.

PM$_{2.5}$ concentrations were recorded during smoking and non-smoking periods; however, it is unclear if levels ever returned to baseline. This would mean we are more likely to be underestimating the difference in concentrations between the smoking and non-smoking periods.

It was not always possible to record exactly when smokers stopped smoking in the hospitality venues (i.e. finished the cigarette or left the premises) due to blocked vision of the smoker, trying to be inconspicuous and having multiple smokers to observe at one time. Individual variation in
smoking behaviour and the presence of ambient smoke after a cigarette was butted out may have artificially increased the background PM$_{2.5}$ levels in the ‘no smoking’ conditions and somewhat washed out the PM$_{2.5}$ levels in the ‘smoker present’ conditions.

In the analyses we have not accounted for the distance and the position of smokers relative to the sampling equipment. During tests, smokers were positioned at varying distances, angles and wind direction from the SidePak. This may have influenced the extent to which the SidePak recorded the PM$_{2.5}$. The furthest recorded distance that a smoker was from the SidePak was approximately 10 metres and even at that venue there was an observed increase in PM$_{2.5}$ concentrations when the smoker lit-up (proximity of smokers to sampling equipment was not routinely recorded and therefore not included as a variable in analyses). Again this may mean non-smokers are actually exposed to higher PM$_{2.5}$ concentrations if they are closer to the smokers, as previous studies have found.14–16

Building awareness of the risks of exposure to SHS through media coverage and other advocacy strategies has played a significant role in developing momentum towards and community acceptance of tobacco control measures to reduce exposure to SHS and smoking prevalence.11 The results of this study can be used for advocacy purposes.

In conclusion, we have demonstrated that even in outdoor well-ventilated areas, SHS levels can be high enough to be a health risk to others nearby. This supports the concept of banning smoking in areas where people may spend extended periods of time, which they may well do in outdoor eating and drinking venues. Legislation to limit smoking in outdoor areas has been implemented in Australia and New Zealand to varying degrees.7 However, this is not consistent and local, state and national governments should be encouraged to legislate against smoking in alfresco eating and drinking places.

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References


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