Vancouver Island Outdoor Smoking Area Air Monitoring Study 2007

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Executive Summary

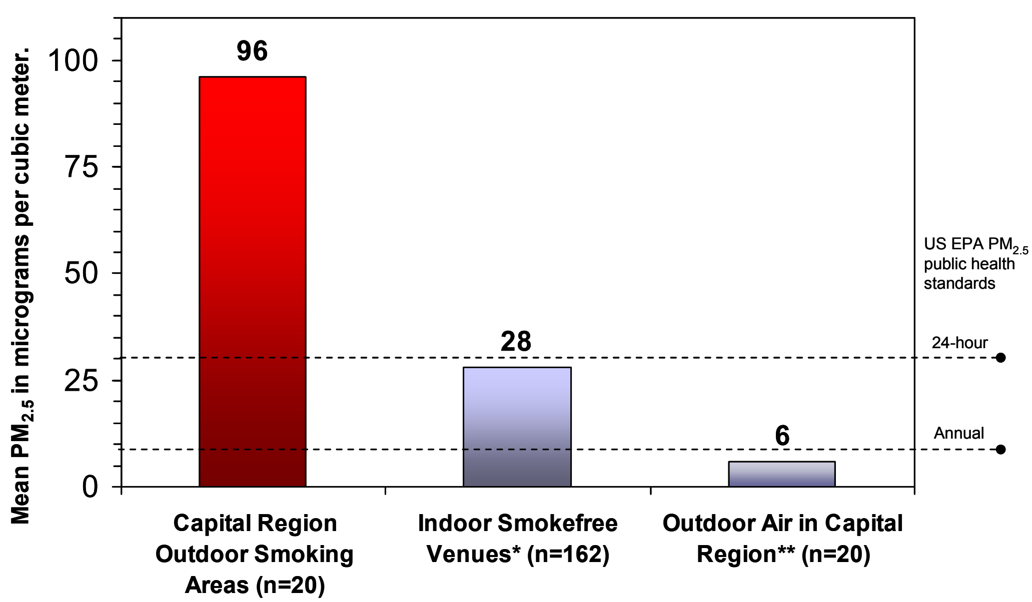
From November to December 2006 air quality was assessed in 20 outdoor smoking areas (OSA) attached to Capital Regional District (CRD) area bars and restaurants. The smoking areas ranged in the degree to which they were enclosed, with some areas being fully enclosed and some being substantially open to the outdoors.

The concentration of fine particle air pollution, $PM_{2.5}$, was measured with a TSI SidePak AM510 Personal Aerosol Monitor. $PM_{2.5}$ is particulate matter in the air smaller than 2.5 microns in diameter. Particles of this size are released in significant amounts from burning cigarettes, are easily inhaled deep into the lungs, and cause a variety of adverse health effects including cardiovascular and respiratory morbidity and death.

Key findings of the study include:

- The average level of fine particle air pollution in outdoor smoking areas was 16 times higher than outdoor background levels and more than 3 times higher than indoor air in smokefree hospitality venues.
- The average fine particle air pollution exposure in outdoor smoking areas was 96 $\mu g/m^3$, which is similar to indoor levels in restaurants and other hospitality venues where smoking is permitted.
- 94% of fine particle pollution exposure in the OSA's was attributed to tobacco smoke.
- Peak 30-second $PM_{2.5}$ exposures in the outdoor smoking areas were 268 $\mu g/m^3$, almost 3 times higher than the average $PM_{2.5}$ exposure.
- The average $PM_{2.5}$ concentration was significantly correlated with the average number of burning cigarettes during the sampling (Spearman's rho=0.68, p<.01).

Figure 1. Average Level of Air Pollution in Capital Region Outdoor Smoking Areas



* 162 smokefree hospitality venues in the U.S. (Travers MJ et al. *Tobacco Smoke Pollution Exposure in Hospitality Venues Around the U.S. and the Effect of Smokefree Air Policies*. Society for Research on Nicotine and Tobacco. Austin, TX. February 23rd 2007)
** Outdoor air measured in Capital Region, after visits to the outdoor smoking areas.

Introduction

Tobacco smoke pollution (TSP) contains at least 250 chemicals that are known to be toxic or carcinogenic, and is itself a known human carcinogen,[1] responsible for an estimated 3,000 lung cancer deaths annually in *never smokers* in the U.S., as well as more than 35,000 deaths annually from coronary heart disease in *never smokers,* and respiratory infections, asthma, Sudden Infant Death Syndrome, and other illnesses in children.[2] In Canada, the mortality toll from TSP exposure exceeds 300 lung cancer[3] and 700 coronary heart disease[4] deaths per year. Although population-based data show declining TSP exposure in the U.S. overall, TSP exposure remains a major public health concern that is entirely preventable.[5, 6] Because requiring smokefree environments is the most effective method for reducing TSP exposure in public places,[7] the Centers for Disease Control and Prevention "Healthy People 2010" Objective 27-13 encourages all states and the District of Columbia to establish and to enforce smokefree air laws in public places and worksites.[8]

Currently in Canada, 9 (out of 13) provinces or territories have comprehensive smokefree workplace legislation that prohibits indoor smoking in public places including restaurants and bars. The provinces/territories are Northwest Territories, Nunavut Territory, New Brunswick, Manitoba, Saskatchewan, Newfoundland and Labrador, Ontario, Quebec, and Nova Scotia. British Columbia and Prince Edward Island have weaker smokefree workplace laws that allow smoking in designated smoking rooms. Alberta restricts smoking only in places where minors are allowed and exempts casinos, bars and bingo halls. Yukon does not have a smokefree law, although its major population center, Whitehorse, has a weak law prohibiting smoking in most public places but allowing designated smoking rooms and allowing smoking in bars. Currently in the U.S., 17 states, Washington, DC, and Puerto Rico have passed strong smokefree air laws that include restaurants and bars. The states are Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Maine, Massachusetts, Montana, New Jersey, New Mexico, New York, Ohio, Rhode Island, Utah, Vermont, and Washington (the Montana and Utah laws include bars in 2009). Arkansas, Florida, Idaho, and Nevada have smokefree air laws that exempt only stand-alone bars. Nevada also exempts casinos. Hundreds of cities and municipalities across the U.S. and Canada have also taken action, as have whole countries including Ireland, Scotland, Uruguay, Norway, New Zealand, Sweden, Italy, Spain and England.

The high levels of exposure to TSP in the hospitality industry have been well established[9-12] and have driven the proliferation of the aforementioned comprehensive smokefree air legislation. As a result of these smoking restrictions, much of the active smoking in hospitality venues has moved to nearby outdoor areas such as patios. Most smokefree air legislation does not restrict smoking in these outdoor areas although Nova Scotia and Newfoundland have restrictions that extend to these outdoor areas of bars and restaurants. Anecdotal evidence indicates that even in places that do have smoking restrictions for outdoor areas these restrictions have poor compliance and are not well enforced. Many of these "outdoor" smoking areas are not really outdoors but are partially or fully enclosed spaces attached to the main building structure. In these cases, we would expect TSP exposures to be similar to indoor places. Whether these "outdoor" smoking spaces are fully or partially enclosed or predominantly open air, there is very little evidence as to what the exposures are to tobacco smoke pollution in these places.

The purpose of this study was to evaluate the air quality in the outdoor smoking areas of bars and restaurants in the Capital Regional District (CRD) in Victoria, British Columbia. The Capital Regional District Clean Air Bylaw that prohibits all indoor smoking has been in place in the CRD since 1999. There are currently no restrictions on smoking in an "outdoor area". In this study an "outdoor smoking area" refers to an area outside of the main bar or restaurant where smoking is permitted although the space may be enclosed to varying degrees. Air quality was assessed in 20 of these outdoor smoking areas attached to bars and restaurants in the CRD. The relation between air pollution and the presence of smoking was assessed. It was hypothesized that air would be more polluted in these outdoor smoking areas compared to background pollution levels and smokefree indoor environments.

Methods

Overview

In November and December 2006 air quality was assessed in the outdoor smoking areas (OSA) of 20 hospitality establishments in the CRD. Visits were attempted to a total of 33 venues although assessments could not be completed in 13 places due to incomplete data (5 places) or because the outdoor smoking areas were closed (8 places).

Measurement Protocol

A 30 minute sample was taken using the TSI Sidepak in the outdoor smoking area of each venue. The number of people in the OSA and the number of burning cigarettes were recorded every 15 minutes during sampling. These observations were averaged over the time in the OSA to determine the average number of people and the average number of burning cigarettes. In addition the proximity of the burning cigarettes was estimated using a sonic measuring device (Zircon DM S40 Sonic Measure, Zircon Corporation, Campbell, CA). The sonic measure was also used to measure the size of the OSA in square meters. Additional observations were also recorded including whether there was a roof and what percent of the OSA was covered by the roof, and what percent of the sides of the OSA were covered by walls, tarps, or other coverings.

A TSI SidePak AM510 Personal Aerosol Monitor (TSI, Inc., St. Paul, MN) was used to sample and record the levels of respirable suspended particles in the air. This device is a laser photometer with a built-in sampling pump that draws air through an attached tube. Its handy size (106 mm × 92 mm × 70 mm) enabled it to be transported inconspicuously and carried over the investigator's shoulder or placed on a table. The device was set to measure $PM_{2.5}$ by attaching a size selective impactor (50% cut-off size at 2.5 μm). This ensured that the vast majority of the mass of secondhand smoke particles was measured by the device while filtering out larger particles (>2.5 microns) that are from other sources. Inside the measuring space, particles reflect laser light, whose intensity is detected at a 90° angle to the laser beam. The device was used with an applied calibration factor of 0.32, which is suitable for tobacco smoke. This calibration factor was determined by comparison to another laser photometer that had been used in previous studies of secondhand smoke measurement.[9] This calibration factor has also been confirmed by other researchers.[13, 14] Klepeis[13] also determined a similar calibration factor was suitable for outdoor tobacco smoke particles. The device was zeroed prior to each use with a filter impermeable to fine dust according to the manufacturer's specifications.

TSI SidePak AM510 Personal Aerosol Monitor

The equipment was set to a 30-second log interval, which averages the previous 30 one-second measurements. Sampling was discreet in order not to disturb the occupants' normal behavior. For each OSA, the first and last minute of logged data were removed because they are averaged with indoors and entryway air. The remaining data points were averaged to provide an average $PM_{2.5}$ concentration within the OSA.

$PM_{2.5}$ is the concentration of particulate matter in the air smaller than 2.5 microns in diameter. Particles of this size are released in significant amounts from burning cigarettes, are easily inhaled deep into the lungs, and are associated with pulmonary and cardiovascular disease and mortality.

Investigators under contract with the Vancouver Island Health Authority did the sampling and researchers from Roswell Park Cancer Institute analyzed the data.

<u>Statistical Analyses</u>

The primary goal was to compare the average $PM_{2.5}$ concentrations in outdoor smoking areas to 1) nearby smokefree outdoor air, and 2) indoor smokefree air in similar hospitality venues. For the comparison to outdoor air, statistical significance was assessed using the Wilcoxon Signed-Rank Test and for the comparison to indoor smokefree air the Mann Whitney U-Test was used. Non-parametric statistical tests are used as the $PM_{2.5}$ levels are not expected to be normally distributed. For this same reason geometric mean values are also presented in addition to the arithmetic means in Table 1. Descriptive statistics including the OSA size (in square meters), percent of OSA with a roof above, percent of enclosed wall space, average number of patrons, average number of burning cigarettes, and average cigarette proximity are reported for each venue and averaged for all venues.

Table 1. Average $PM_{2.5}$ Level in Each Capital Region Outdoor Smoking Area

Venue #	Size (m^2)	Roof Area Covered (%)	Wall Area Covered (%)	People (mean)	Cigarettes (mean)	Average Cigarette Proximity (m)	Peak 30-second $PM_{2.5}$ (µg/m^3)	Average $PM_{2.5}$ (µg/m^3)	Background $PM_{2.5}$ (µg/m^3)*	TSP $PM_{2.5}$ (µg/m^3)**
1	28	65	30	8.3	2.3	1.8	171	40	3	37
2	40	100	95	1.0	1.0	1.8	100	16	3	13
3	54	100	98	7.0	3.0	1.5	105	32	3	29
4	45	100	90	5.0	3.7	2.0	273	102	3	99
5	45	100	98	21.3	8.7	1.1	692	365	3	362
6	28	100	98	13.0	3.0	1.1	523	227	11	216
7	46	100	90	17.3	6.0	1.1	74	45	14	31
8	66	100	95	10.0	2.7	1.5	429	256	14	242
9	40	100	98	1.7	1.7	2.5	139	52	6	46
10	55	80	60	4.7	3.3	1.8	343	74	6	68
11	35	15	30	1.7	1.7	0.9	112	12	2	10
12	35	95	80	3.0	1.3	1.0	130	12	2	10
13	45	100	100	10.3	4.7	1.5	191	37	6	31
14	41	100	80	12.3	7.3	1.7	137	61	6	55
15	48	90	90	8.7	4.0	2.1	144	78	6	72
16	34	100	90	11.0	6.0	1.3	1318	430	6	424
17	12	100	70	0.7	0.7	1.8	14	8	7	1
18	33	100	80	0.7	0.7	2.5	398	47	6	41
19	28	100	80	8.3	2.7	2.1	63	19	4	15
20	45	100	85	0.5	0.5	2.0	13	6	7	-1
Mean	***40***	***92***	***82***	***7.3***	***3.2***	***1.7***	***268***	***96***	***6***	***90***
Geometric Mean	***38***	***87***	***78***	***4.5***	***2.5***	***1.6***	***158***	***48***	***5***	***35***†

* Nearby measured outdoor $PM_{2.5}$ concentration.

** $PM_{2.5}$ concentration attributable to tobacco smoke pollution.

† TSP $PM_{2.5}$ for venue 20 was changed to "+1" in order to calculate geometric mean.

Results

A summary of each location visited is shown in Table 1. The average $PM_{2.5}$ level in the 20 outdoor smoking areas was 96 $\mu g/m^3$, 16 times higher than the level (6 $\mu g/m^3$) measured in nearby, smokefree, outdoor air. This difference is statistically significant according to the Wilcoxon Signed-Rank Test ($p<0.001$). The average $PM_{2.5}$ level in the outdoor smoking areas is also 3.4 time higher than the average in a large cross-sectional sample of 162 smokefree hospitality venues in the U.S.[12] This difference is statistically significant according to the Mann Whitney U-Test ($p<0.001$). These comparisons are shown in Figure 1.

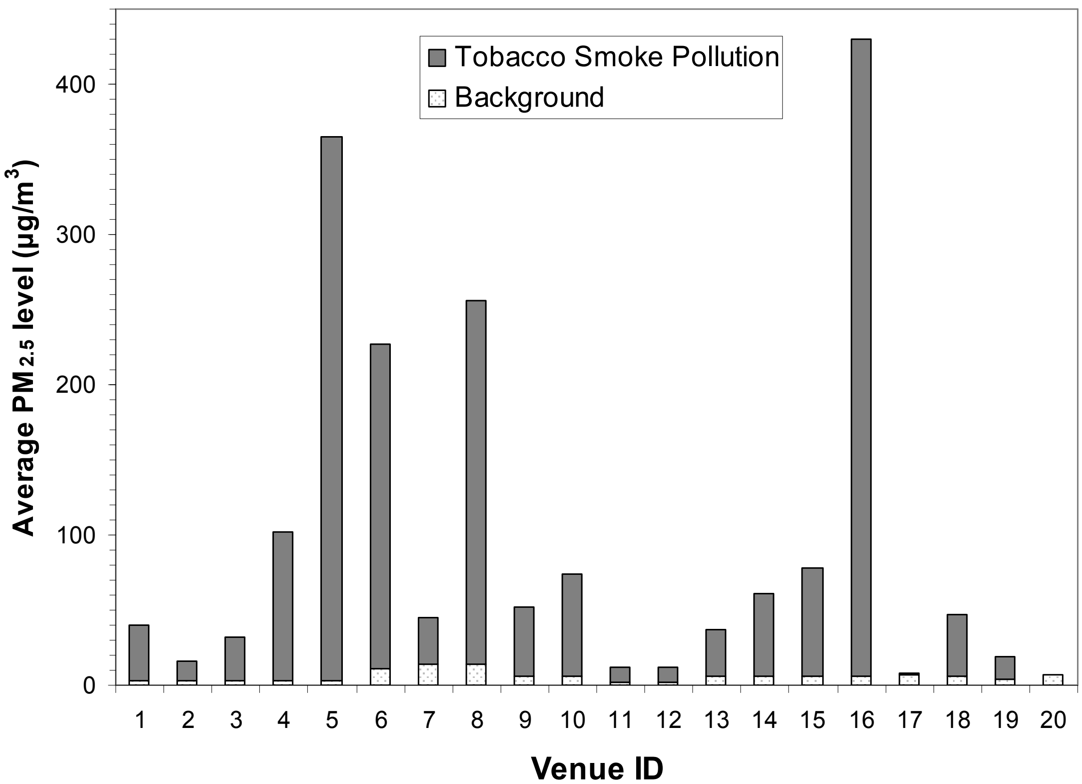
The range of average $PM_{2.5}$ concentrations in the OSA's varied greatly from a minimum of 6 $\mu g/m^3$ to a maximum of 430 $\mu g/m^3$. In general the peak 30-second $PM_{2.5}$ concentrations far exceeded the average recorded levels. The average peak concentration was 268 $\mu g/m^3$ and the maximum peak exposure was 1,318 $\mu g/m^3$.

The wide range in average $PM_{2.5}$ levels was primarily explained by the average number of burning cigarettes. The overall average number of burning cigarettes in this study was 3.2. The average $PM_{2.5}$ level was significantly correlated with the average number of burning cigarettes (Spearman's rho=0.68, p=0.001) but was not significantly correlated with amount of roof area, amount of closed wall area, average cigarette proximity, or size of the OSA.

Fifteen of the 20 OSA's (75%) had a roof covering 100% of the area. Eleven OSA's (55%) had an estimated 90% or more of the surrounded wall areas covered by walls, tarps or other similar barriers.

Outdoor, background $PM_{2.5}$ levels were very low (6 $\mu g/m^3$), and an estimated 94% of particle exposure in the outdoor smoking areas was attributable to tobacco smoke. Figure 2 shows the average $PM_{2.5}$ concentration measured at each of the 20 OSA's and shows how much of the $PM_{2.5}$ concentration was attributable to tobacco smoke and to outdoor background levels.

Figure 2. Level of Air Pollution in Capital Region Outdoor Smoking Areas



The real-time plots showing the level of air pollution in each venue sampled are presented in the Appendix in Figures 3 through 8. Note that the scale on the y-axis varies according to the data in each figure. The real-time $PM_{2.5}$ plots throughout the duration of sampling reveal the following results: 1) low background levels are observed outdoors, away from the OSA's; 2) much higher levels of air pollution are generally observed in the outdoor smoking areas; and 3) peak exposure levels in the outdoor smoking areas can reach levels far in excess of the average recorded level.

Discussion

The United States Environmental Protection Agency (EPA) cited over 80 epidemiologic studies in creating a particulate air pollution standard in 1997.[15] The EPA has recently updated this standard and, in order to protect the public health, the EPA has set limits of 15 $\mu g/m^3$ as the average annual level of $PM_{2.5}$ exposure and 35 $\mu g/m^3$ for 24-hour exposure.[15, 16] The EPA has also developed the Air Quality Index (AQI) which reports daily air quality based on 5 of the 6 "criteria air pollutants", which include $PM_{2.5}$. The AQI is a uniform color-coded index that forecasts air quality and provides information to the public about air quality and associated health effects. Air quality health advisories and warnings are issued based on the current AQI and forecasted AQI and are intended to warn the public about health effects that may be experienced a few hours or days after breathing polluted air. The AQI in the appendix shows the $PM_{2.5}$ concentrations corresponding to the various health warnings. While the AQI is based on 24-hour particle exposures and this study only measured 30 minute average exposures, the EPA standards still provide a useful comparison to put the fine particle pollution levels seen in this study into context.

The air quality was "good" according to the AQI in only 20% of the OSA's. Fifty percent of the OSA's had air quality that was "unhealthy for sensitive groups" or worse. In fact 3 OSA's (15%) had air quality in the "hazardous" range, the worst category of outdoor air pollution. Based on the latest scientific evidence, the EPA staff currently proposes even lower $PM_{2.5}$ standards to adequately protect the public health,[17] making the high $PM_{2.5}$ exposures of people in smoking environments even more alarming.

This study demonstrates that fine particle air pollution in outdoor smoking areas occurs at harmful levels similar to what is seen in indoor smoking environments. There is significant exposure to tobacco smoke pollution in these OSA's even though smoking rates during sampling were relatively low, with an average number of burning cigarettes of only 3.2.

There are no known published studies on the levels of tobacco smoke pollution exposure in these outdoor smoking areas but these results can be compared to similar studies of indoor air quality in relation to the presence of smoking. Ott et al. did a study of a single tavern in California and showed an 82% average decrease in RSP levels after smoking was prohibited by a city ordinance.[18] Repace studied 8 hospitality venues, including one casino, in Delaware before and after a statewide prohibition of smoking in these types of venues and found that about 90% of the fine particle pollution could be attributed to tobacco smoke.[9] Similarly, in a study of 22 hospitality venues in Western New York, Travers et al. found a 90% reduction in RSP levels in bars and restaurants, an 84% reduction in large recreation venues such as bingo halls and bowling alleys, and a 58% reduction even in locations where only SHS from an adjacent room was observed at baseline.[11] A cross-sectional study of 53 hospitality venues in 7 major cities across the U.S. showed 82% less indoor air pollution in the locations subject to smokefree air laws, even though compliance with the laws was less than 100%.[19] These studies documented average indoor tobacco smoke particle levels ranging from 55 $\mu g/m^3$ to 293 μg/m^3. Similarly, this study showed an average $PM_{2.5}$ concentration in OSA's of 96 μg/m^3.

Other studies have directly assessed the effects SHS exposure has on human health. One study found that respiratory health improved rapidly in a sample of bartenders after a state smokefree workplace law was implemented in California[20], and another study reported a 40% reduction in acute myocardial infarctions in patients admitted to a regional hospital during the 6 months that a local smokefree ordinance was in effect.[21] Smokefree legislation in Scotland was associated with significant early improvements in symptoms, lung function, and systemic inflammation of all bar workers, while asthmatic bar workers also showed reduced airway inflammation and improved quality of life.[22] Farrelly et al. also showed a significant decrease in both salivary cotinine concentrations and sensory symptoms in hospitality workers after New York State's smokefree law prohibited smoking in their worksites.[23]

The effects of passive smoking on the cardiovascular system in terms of increased platelet aggregability, endothelial dysfunction, increased arterial stiffness, increased atherosclerosis, increased oxidative stress and decreased antioxidant defense, inflammation, decreased energy production in the heart muscle, and a decrease in the parasympathetic output to the heart, are often nearly as large (averaging 80% to 90%) as chronic active smoking. Even brief exposures to SHS, of minutes to hours, are associated with many of these cardiovascular effects. The effects of secondhand smoke are substantial and rapid, explaining the relatively large health risks associated with secondhand smoke exposure that have been reported in epidemiological studies.[24]

The hazardous health effects of exposure to second-hand smoke are now well-documented and established in various independent research studies and numerous international reports. The body of scientific evidence is overwhelming: there is no doubt within the international scientific community that second-hand smoke causes heart disease, lung cancer, nasal sinus cancer, sudden infant death syndrome (SIDS), asthma and middle ear infections in children and various other respiratory illnesses. There is also evidence suggesting second-hand smoke exposure is also causally associated with stroke, low birthweight, spontaneous abortion, negative effects on the development of cognition and behavior, exacerbation of cystic fibrosis, cervical cancer and breast cancer. The health effects of secondhand smoke exposure are detailed in recent reports by the California Environmental Protection Agency[25] and the U.S. Surgeon General[26].

Conclusions

Outdoor smoking areas of CRD bars and restaurants are significantly more polluted than outdoor smokefree air. Fine particle air pollution levels in these outdoor smoking areas are similar to indoor smoking environments and on average exceed US EPA health standards for fine particle pollution exposure. These outdoor smoking areas pose a health hazard for exposed nonsmoking employees and patrons. These data should be taken into account when formulating public policy to eliminate nonsmoker exposure to hazardous tobacco smoke pollution.

Acknowledgments

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Support for Roswell Park Cancer Institute researchers was also provided by the Flight Attendant Medical Research Institute.

Appendix

U.S. Environmental Protection Agency Air Quality Index		
Air Quality Index Levels of Health Concern	$PM_{2.5}$ ($\mu g/m^3$)	Meaning
Good	≤15	Air quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	16-40	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	41-65	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	66-150	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	151-250	Health alert: everyone may experience more serious health effects.
Hazardous	≥251	Health warnings of emergency conditions. The entire population is more likely to be affected.

Real-time plots start on the following page.

Figure 3. Capital Region Air Monitoring Study – November 23, 2006

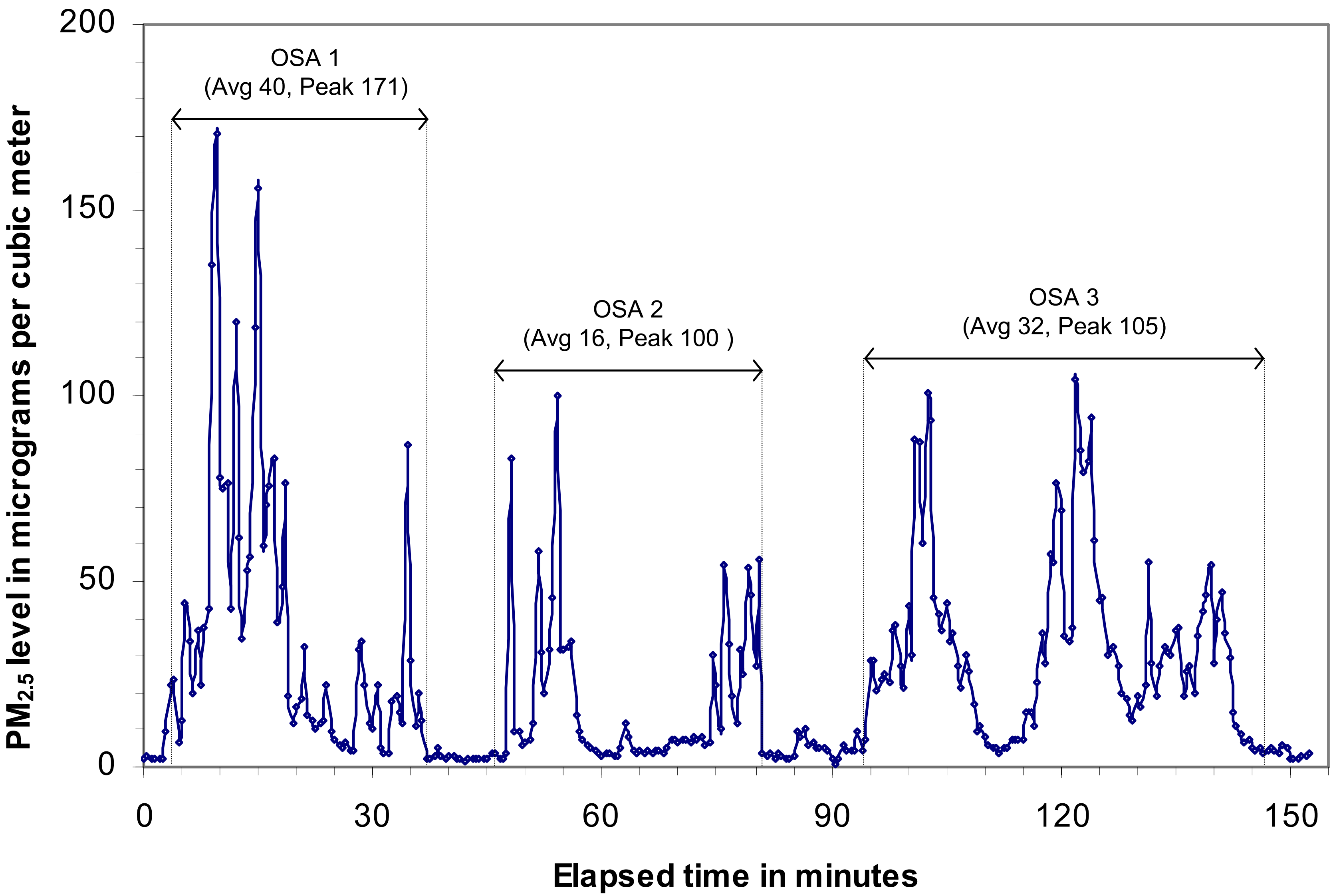


Figure 4. Capital Region Air Monitoring Study – November 24, 2006

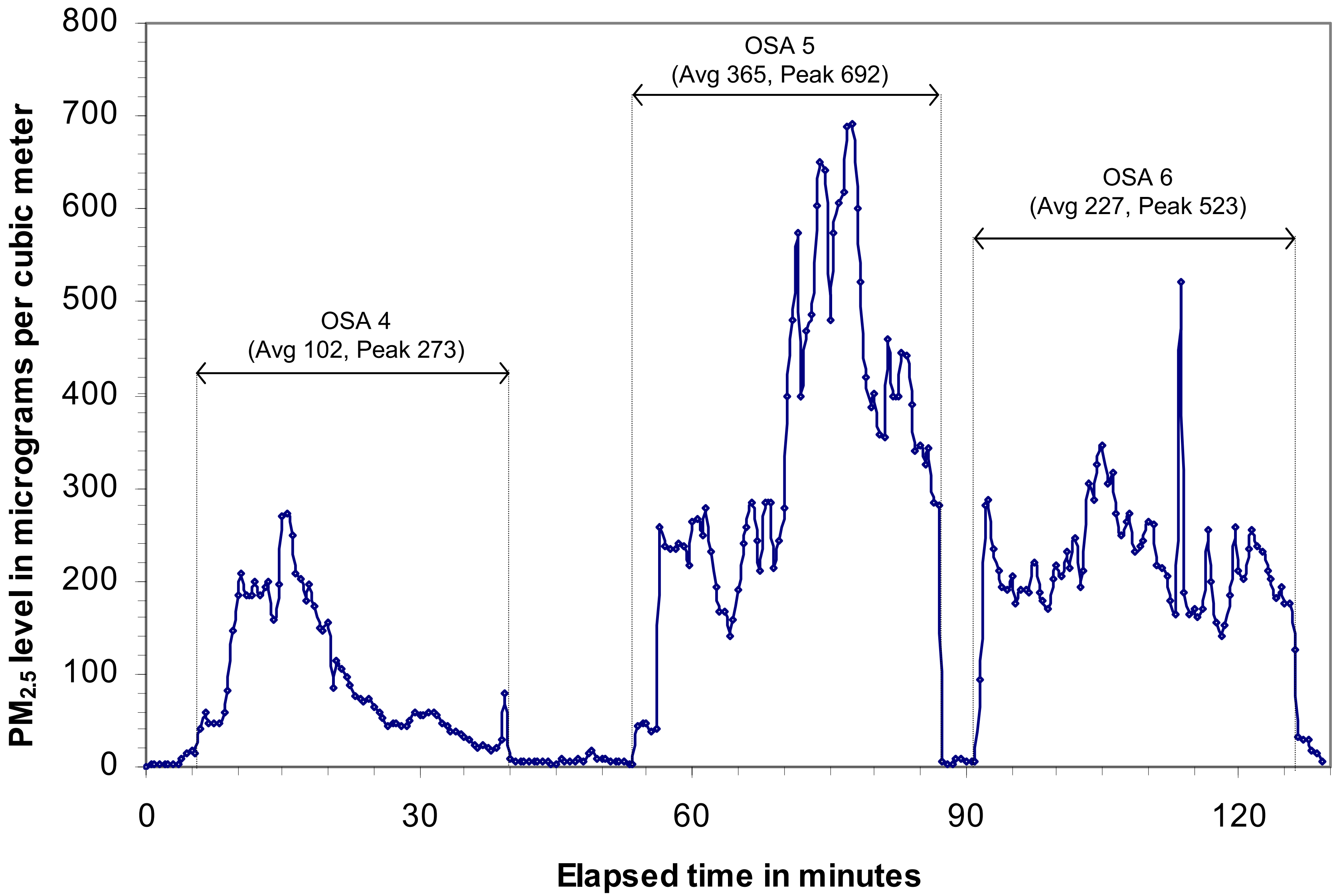


Figure 5. Capital Region Air Monitoring Study – December 2, 2006

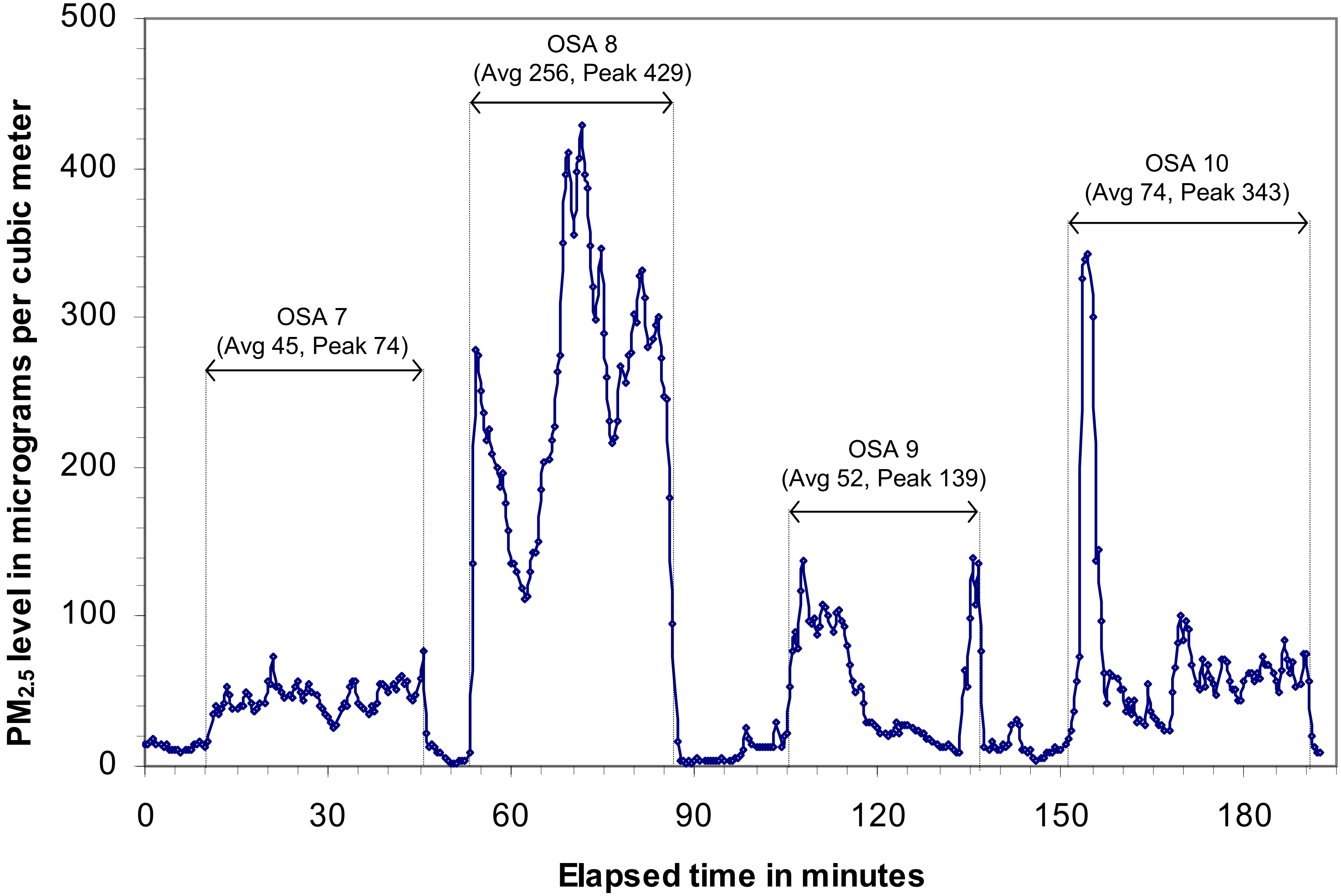


Figure 6. Capital Region Air Monitoring Study – December 21, 2006

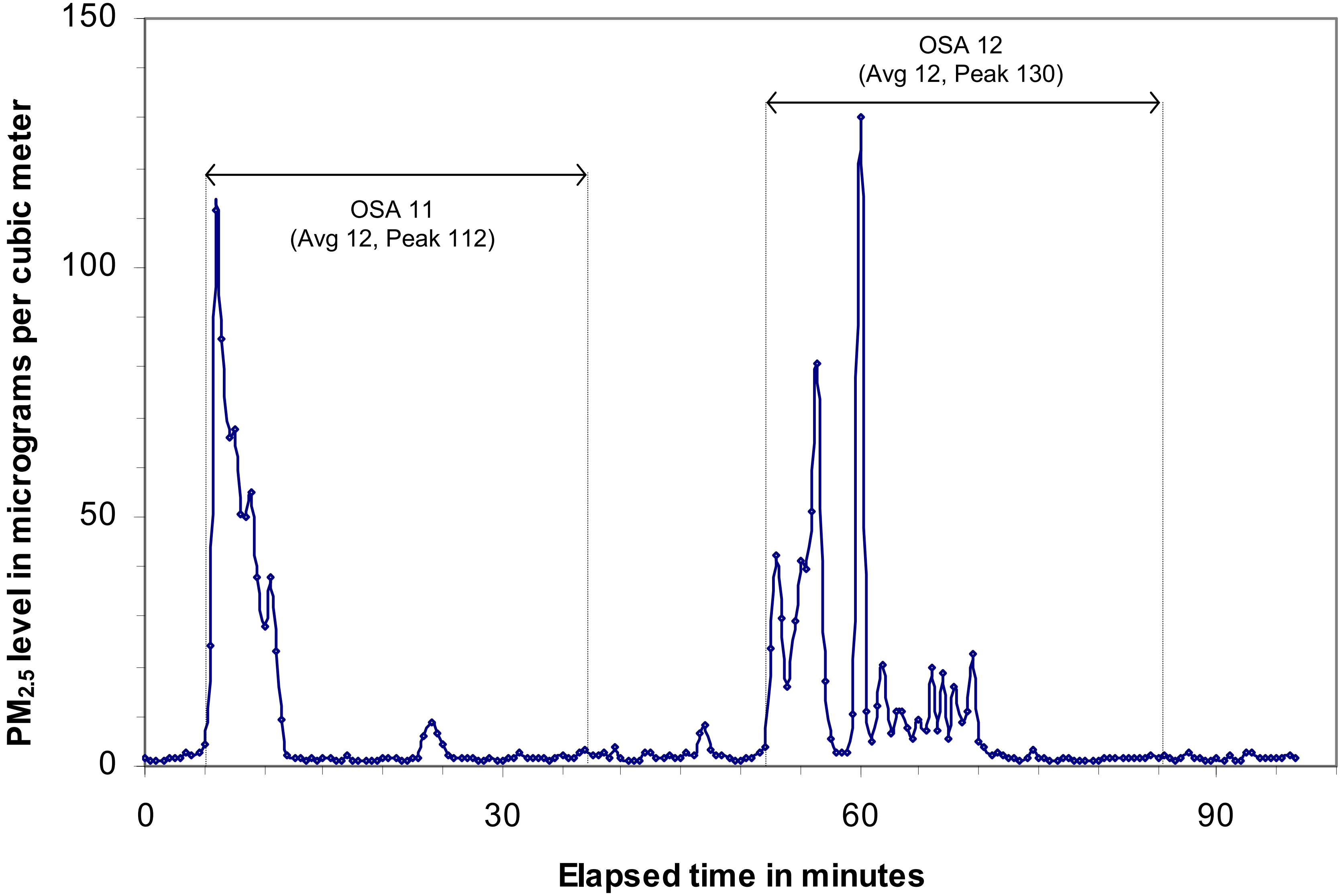


Figure 7. Capital Region Air Monitoring Study – December 22, 2006

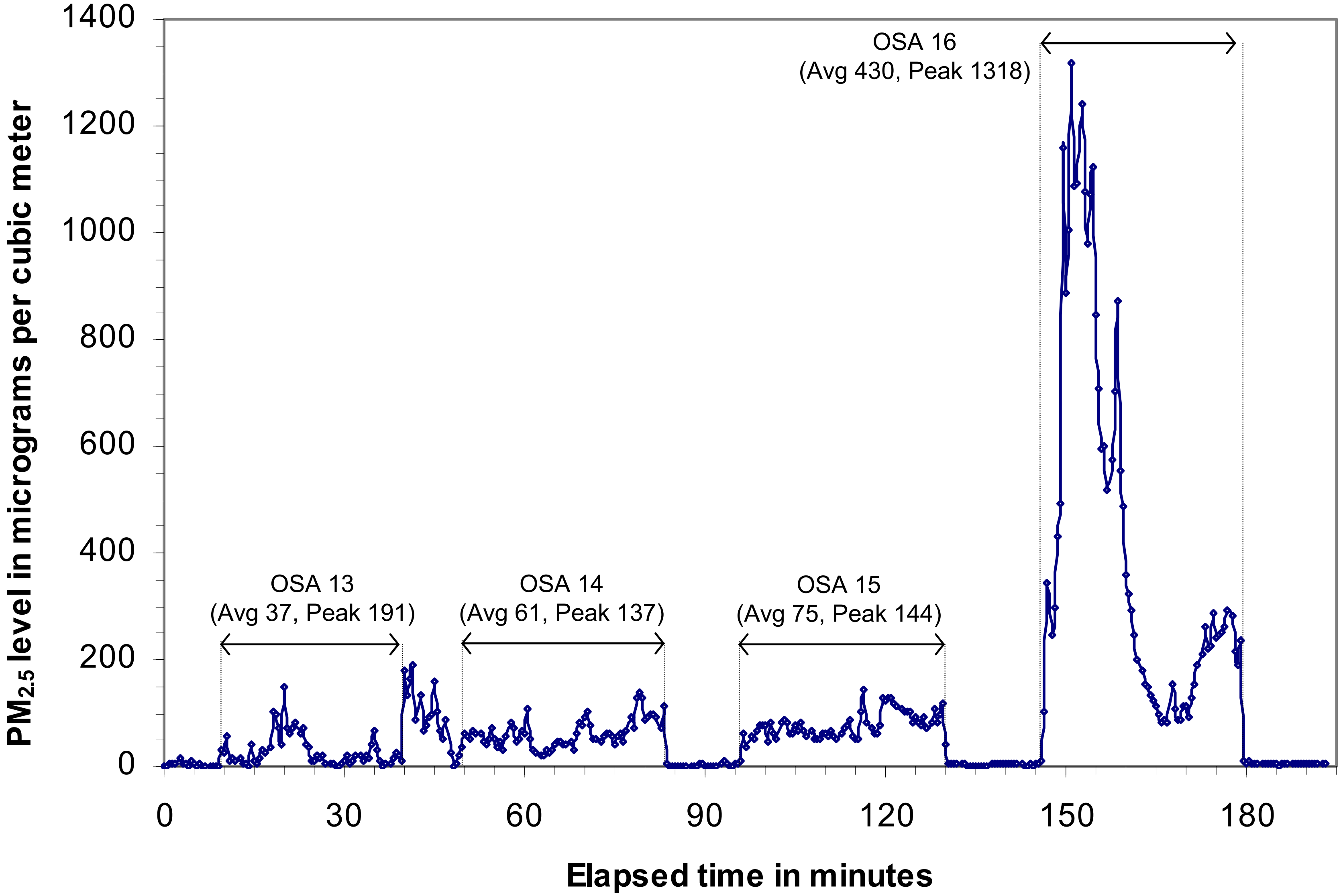
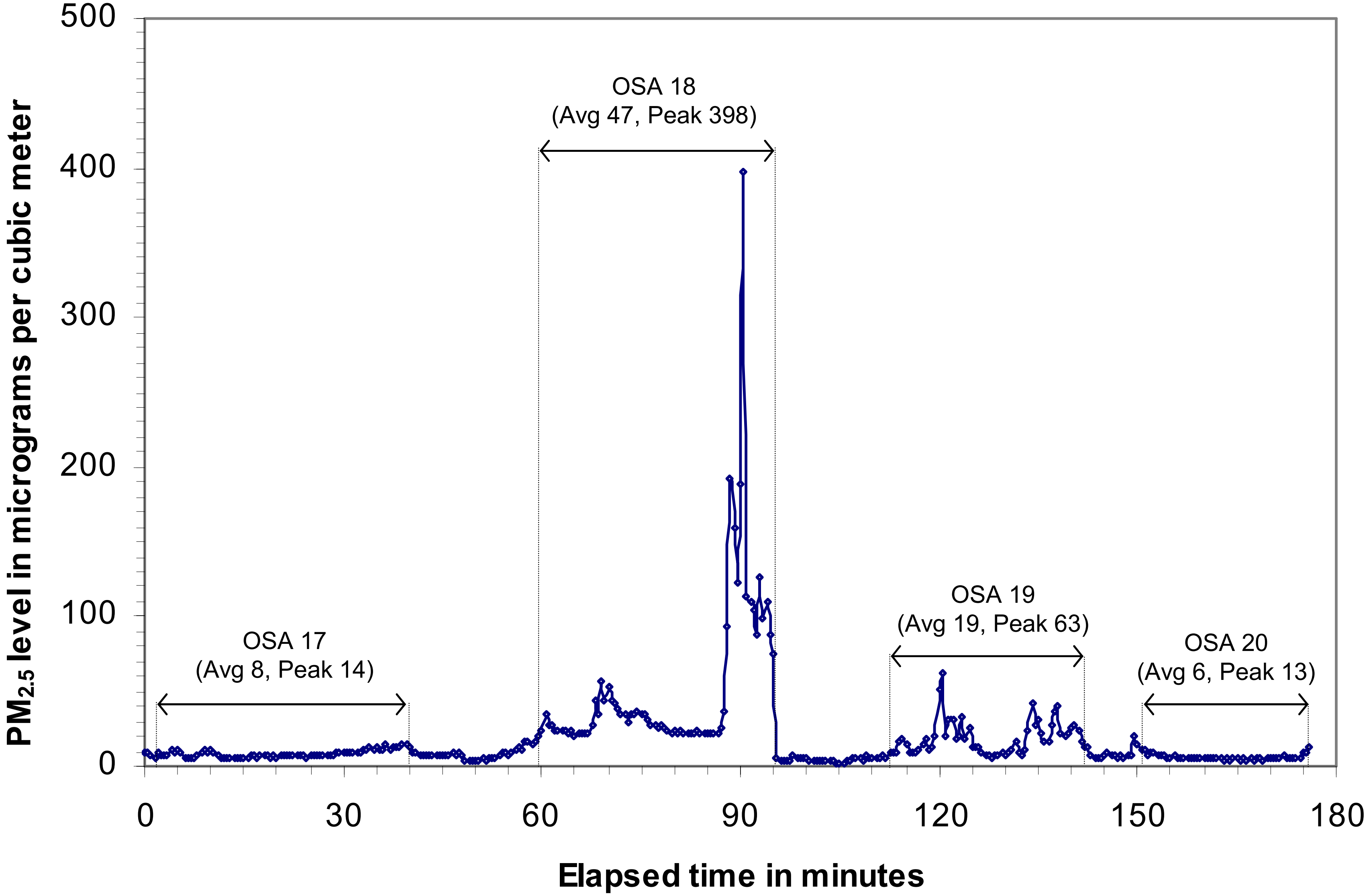


Figure 8. Capital Region Air Monitoring Study – December 28, 2006



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