# New Jersey Air Monitoring Study

# August 18th to September 27th, 2005

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**Executive Summary**

Indoor air quality was assessed in 51 New Jersey locations, in 13 of New Jersey's 21 counties, between August 18th and September 27th, 2005 using the TSI SidePak AM510 Personal Aerosol Monitor that measures $PM_{2.5}$. $PM_{2.5}$ 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 cause a variety of adverse health effects including cardiovascular and respiratory morbidity and death.

Sites tested included 15 smoking-permitted restaurants and diners, some with alcoholic beverage service, and some with bars; 16 smoking-permitted bars, including neighborhood bars, bar clubs catering to young adults, sports bars, university-area bars, a go-go bar, and bars that had food service but were primarily bars; 9 smoking-permitted casinos; and 3 smoking-permitted bowling alleys. Eight smoke-free restaurants and diners, including some with alcoholic beverage service and bars, were tested.

Key findings of the study include:

- The level of indoor air pollution in smoke-free restaurants, as measured by average $PM_{2.5}$ level, was 84% lower than bowling alleys, 87% lower than casinos, 88% lower than restaurants allowing smoking and 96% lower than bars in this study.
- Employees in all (43 of 43) of the locations allowing indoor smoking are exposed to levels of particulate matter in excess of levels recommended by the Environmental Protection Agency (EPA) to protect public health. If we assume only background exposure to fine particle air pollution outside work, full-time employees in the locations in this study are exposed, on average, to 3.4 times the annual EPA exposure limit of fine particulate air pollution, with a range of between 1.3 and 25 times the limit.
- Employees in all (8 of 8) smoke-free locations had fine particle exposures below EPA exposure limits.

Locations allowing indoor smoking are significantly more polluted than indoor smoke-free sites and than outdoor air in New Jersey, with levels of pollution in excess of EPA standards. This study demonstrates that workers and patrons in New Jersey are exposed to harmful levels of secondhand smoke, a known human carcinogen and toxin. Policies that prohibit smoking in public worksites dramatically reduce secondhand smoke exposure and improve worker and patron health.

## Introduction

Secondhand smoke (SHS) contains at least 250 chemicals that are known to be toxic or carcinogenic, and is itself a known human carcinogen[i], responsible for an estimated 3,000 lung cancer deaths annually in *never smokers* in the U.S., as well as over 35,000 deaths annually from coronary heart disease in *never smokers,* plus respiratory infections, asthma, Sudden Infant Death Syndrome, and other illnesses in children[ii]. Although population-based data show declining SHS exposure in the U.S. overall, SHS exposure remains a major public health concern that is entirely preventable[iii,iv]. Because policies requiring smoke-free environments are the most effective method for reducing SHS exposure in public places[v], Healthy People 2010 Objective 27-13[vi] encourages all states and the District of Columbia to establish laws on smoke-free indoor air that prohibit smoking or limit it to separately ventilated areas in public places and worksites. Currently, 9 states (California, Delaware, New York, Connecticut, Maine, Massachusetts, Rhode Island, Montana and Vermont), which represent approximately 24% of the U.S. population, have comprehensive clean indoor air regulations in force that cover virtually all indoor worksites including bars and restaurants. In addition, voters in Washington State just approved a ballot initiative making Washington the 10th comprehensive smoke-free state. The Washington State law goes into effect in December 2005.

The overall purpose of the New Jersey Air Monitoring Study was to examine indoor air quality in a sample of smoke-free and smoking-permitted New Jersey hospitality venues including bars, restaurants, bowling alleys, and casinos. The relation between indoor air pollution and the presence of on-premises smoking was assessed. It was hypothesized that indoor air would be less polluted in those venues where smoking is prohibited and where smoking does not occur, than in those places where smoking is present. New Jersey casinos were included in this study since they are popular entertainment venues employing and entertaining millions of people annually and there is little data on secondhand smoke exposure in casinos.

## Methods

Overview

Between August 18th and September 27th, 2005, indoor air quality was assessed in 51 indoor locations across the state of New Jersey. The locations were in 13 of New Jersey's 21 counties, including Atlantic (10 sites), Bergen (3), Essex (1), Hudson (6), Hunterdon (1), Middlesex (4), Monmouth (3), Morris (6), Ocean (5), Passaic (1), Somerset (3), Union (5), and Warren (3). Testing was done throughout the days of the week from early morning through midnight and later. Tested sites were in urban, suburban, and rural areas and included blue collar, middle class, and upscale establishments. Some sites were individually-owned establishments and some were part of local or national chain entities. Sites tested included 15 smoking-permitted restaurants and diners, some with alcoholic beverage service, and some with bars; 16 smoking-permitted bars, including neighborhood bars, bar clubs catering to young adults, sports bars, university-area bars, a go-go bar, and bars that had food service but were primarily bars; 9 smoking-permitted casinos; and 3 smoking-permitted bowling alleys. Eight

smoke-free restaurants and diners, including some with alcoholic beverage service and bars, were tested.

Measurement Protocol

A minimum of 30 minutes was spent in each venue. The number of people inside the venue and the number of burning cigarettes were recorded every 15 minutes during sampling. These observations were averaged over the time inside the venue to determine the average number of people on the premises and the average number of burning cigarettes. The Zircon DM S50 Sonic Measure (Zircon Corporation, Campbell, CA) was used to measure room dimensions and hence the volume of each of the venues. The active smoker density was calculated by dividing the average number of burning cigarettes by the volume of the room in meters.

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. The SidePak uses a built-in sampling pump to draw air through the device where the particulate matter in the air scatters the light from a laser to assess the real-time concentration of particles smaller than 2.5µm in micrograms per cubic meter, or $PM_{2.5}$. The SidePak was calibrated against a laser photometer, which had been previously calibrated and used in similar studies. In addition, the SidePak was zero-calibrated prior to each use by attaching a HEPA filter according to the manufacturer's specifications.

TSI SidePak AM510 Personal Aerosol Monitor


The equipment was set to a one-minute log interval, which averages the previous 60 one-second measurements. Sampling was discreet in order not to disturb the occupants' normal behavior. For each venue, the first and last minute of logged data were removed because they are averaged with outdoors and entryway air. The remaining data points were averaged to provide an average $PM_{2.5}$ concentration within the venue.

***$PM_{2.5}$ 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.***

Roswell Park Cancer Institute staff provided the equipment, trained the New Jersey testers, and accompanied them at the initial sites. Teams composed of New Jersey GASP and American Cancer Society staff members and volunteers did the testing.

Statistical Analyses

The primary goal was to assess the difference in the average levels of $PM_{2.5}$ in a cross-sectional sample of places that were smoke-free and places that were not, which is assessed with the Mann Whitney U-test. Descriptive statistics including the venue volume, number of patrons, and average smoker density (i.e. number of burning cigarettes per 100 $m^3$) are also reported for each venue and averaged for all venues. The analyses were also stratified by type of venue; smoke-free restaurants, bowling centers, casinos, smoking-permitted restaurants, and bars.

**Table 1.** Summary of Each Location Visited, New Jersey, August 18 to September 27, 2005

| Venue Number | County | Type | Smoke-free?* | Date Sampled | Size ($m^3$) | Active smoker density** | Average $PM_{2.5}$ level ($\mu g/m^3$) |
|---|---|---|---|---|---|---|---|
| 1 | Union | restaurant w/o bar | Yes | 8/18/2005 | 267 | 0.00 | 14 |
| 2 | Union | restaurant w bar | No | 8/18/2005 | 620 | 0.32 | 225 |
| 3 | Somerset | restaurant w bar | No | 8/18/2005 | 2076 | 0.16 | 50 |
| 4 | Somerset | bar w food avail | No | 8/18/2005 | 464 | 0.79 | 179 |
| 5 | Union | restaurant w bar | No | 8/18/2005 | 498 | 0.65 | 137 |
| 6 | Union | diner | No | 8/19/2005 | 176 | 0.38 | 41 |
| 7 | Hudson | restaurant w/o bar | Yes | 8/26/2005 | 101 | 0.00 | 9 |
| 8 | Hudson | bar | No | 8/26/2005 | 84 | 2.38 | 83 |
| 9 | Hudson | restaurant w bar | Yes | 8/26/2005 | 248 | 0.00 | 17 |
| 10 | Hudson | bar | No | 8/26/2005 | 224 | 0.74 | 929 |
| 11 | Hudson | bar | No | 8/26/2005 | 340 | 1.96 | 1196 |
| 12 | Monmouth | bar, club | No | 8/27/2005 | 2832 | 1.32 | 827 |
| 13 | Monmouth | bar w food avail | No | 8/27/2005 | 389 | 0.94 | 462 |
| 14 | Monmouth | bar, club w. food | No | 8/27/2005 | 883 | 0.30 | 388 |
| 15 | Somerset | rest w bar | Yes | 8/29/2005 | 432 | 0.00 | 13 |
| 16 | Morris | diner | No | 8/29/2005 | 505 | 0.20 | 124 |
| 17 | Essex | rest w bar | No | 8/29/2005 | 934 | 0.21 | 47 |
| 18 | Bergen | diner | No | 9/1/2005 | 612 | 0.07 | 35 |
| 19 | Bergen | diner | No | 9/1/2005 | 453 | 0.07 | 91 |
| 20 | Passaic | diner | No | 9/1/2005 | 459 | 0.29 | 41 |
| 21 | Hudson | diner | No | 9/1/2005 | 879 | 0.18 | 58 |
| 22 | Bergen | rest w bar | No | 9/1/2005 | 446 | 0.17 | 40 |
| 23 | Atlantic | casino | No | 9/2/2005 | N/A*** | N/A | 115 |
| 24 | Atlantic | restaurant | Yes | 9/2/2005 | 354 | 0.00 | 12 |
| 25 | Atlantic | casino | No | 9/2/2005 | N/A | N/A | 75 |
| 26 | Atlantic | casino | No | 9/2/2005 | N/A | N/A | 81 |
| 27 | Atlantic | casino | No | 9/2/2005 | N/A | N/A | 102 |
| 28 | Middlesex | bar w rest | No | 9/6/2005 | 204 | 0.33 | 65 |
| 29 | Middlesex | bar | No | 9/6/2005 | 182 | 1.28 | 101 |
| 30 | Middlesex | bar | No | 9/6/2005 | 126 | 1.32 | 172 |
| 31 | Middlesex | rest | Yes | 9/6/2005 | 204 | 0.00 | 7 |
| 32 | Warren | diner | No | 9/8/2005 | 352 | 0.85 | 213 |
| 33 | Warren | bowling center | No | 9/8/2005 | 1291 | 0.29 | 104 |
| 34 | Warren | bar w rest | No | 9/8/2005 | 181 | 0.69 | 92 |
| 35 | Hunterdon | bar | No | 9/8/2005 | 348 | 0.48 | 196 |
| 36 | Morris | bar | No | 9/8/2005 | 252 | 1.49 | 232 |
| 37 | Morris | diner | Yes | 9/9/2005 | 255 | 0.00 | 18 |
| 38 | Union | rest w bar | No | 9/9/2005 | 267 | 0.19 | 151 |
| 39 | Morris | rest w bar | No | 9/10/2005 | 159 | 0.47 | 58 |
| 40 | Morris | bar w food avail | No | 9/10/2005 | 154 | 0.65 | 227 |
| 41 | Morris | rest and bar | Yes | 9/10/2005 | 280 | 0.00 | 4 |
| 42 | Atlantic | casino | No | 9/10/2005 | N/A | N/A | 75 |
| 43 | Atlantic | casino | No | 9/10/2005 | N/A | N/A | 122 |
| 44 | Atlantic | casino | No | 9/10/2005 | N/A | N/A | 73 |
| 45 | Atlantic | casino | No | 9/11/2005 | N/A | N/A | 76 |
| 46 | Atlantic | casino | No | 9/11/2005 | N/A | N/A | 110 |
| 47 | Ocean | rest w bar | No | 9/16/2005 | 833 | 4.80 | 135 |
| 48 | Ocean | bowling center | No | 9/17/2005 | 3982 | 0.03 | 49 |
| 49 | Ocean | bar | No | 9/17/2005 | 1338 | 1.79 | 115 |
| 50 | Ocean | bowling center | No | 9/26/2005 | 5947 | 0.32 | 71 |
| 51 | Ocean | bar | No | 9/26/2005 | 1407 | 0.78 | 154 |
| Avg. | | | | | 763 | 0.64 | 157 |

* Used to compare indoor air pollution levels between places that are smoke-free and places that are not.

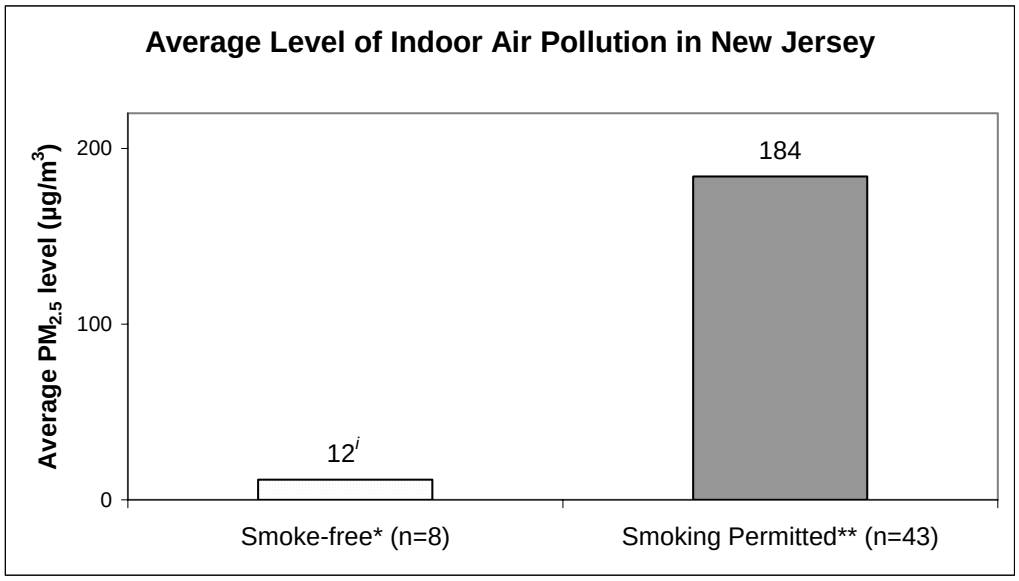
** Average number of burning cigarettes per $100m^3$

*** Due to the massive size and large number of people in the casinos it was not possible to determine room volumes, people counts or burning cigarette counts

## Results

Overall, 51 indoor sites were visited including 8 smoke-free restaurants, 3 bowling alleys, 9 casinos, 15 restaurants allowing smoking, and 16 bars. A summary of each location visited is shown in Table 1. The average $PM_{2.5}$ level in the 8 smoke-free locations was 12 $\mu g/m^3$. Forty-two places were sampled that allowed smoking in the establishment, and the average $PM_{2.5}$ level in these venues was 184 $\mu g/m^3$ (Figure 1). The level of indoor air pollution was 93% lower in the venues that were smoke-free compared to those where smoking was permitted. Due to the massive size and large number of people present in the casinos the average number of people, room volume and average smoker density was not assessed in these 9 locations. The average size of the 42 locations that were not casinos was 763 $m^3$, with the smoke-free venues being on average smaller than the locations permitting smoking (268 $m^3$ vs. 879 $m^3$). The overall average number of people present during sampling was 54, and consistent with their smaller size, the smoke-free sites had fewer people on average than the smoking permitted sites (18 vs. 63). The average smoker density was significantly higher in the smoking permitted locations (0.79 burning cigarettes per 100 $m^3$) compared to the smoke-free locations (0.00 burning cigarettes per 100 $m^3$). No smoking was observed in any of the locations with smoke-free policies.

**Figure 1.** Fine Particle Air Pollution in All New Jersey Venues, August 18, 2005 to September 27, 2005




[i] p-value < 0.001 for comparison of smoke-free sites to smoking permitted sites (Mann Whitney U-test)

* Smoke-free restaurants and diners; some with alcoholic beverage service, some with bars

** These locations without smoking restrictions include bars, restaurants, diners and casinos

The locations visited were also stratified by type of location with the five strata being smoke-free restaurants, smoking bowling centers, smoking casinos, smoking restaurants, and smoking bars. Aside from the smoke-free restaurants, all of the other groups allowed indoor smoking. The number of locations in each group, the average size, average

number of people present, average number of burning cigarettes, average active smoker density and average $PM_{2.5}$ level are all shown in Table 2.

**Table 2.** Average New Jersey Indoor Air Pollution Levels by Type of Venue

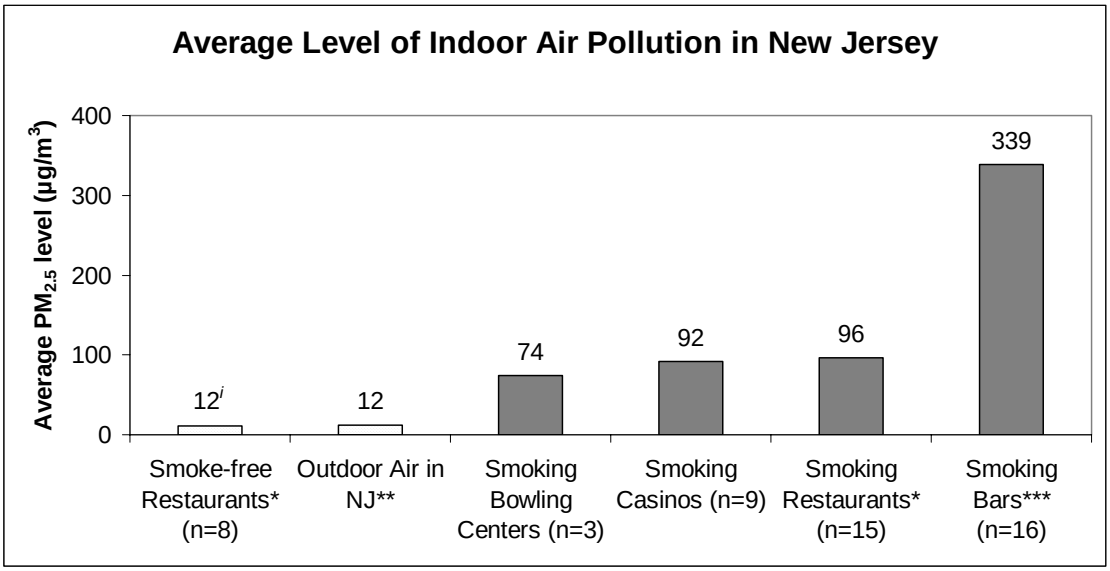
| Type of Venue | Sample Size | Average Size ($m^3$) | Average # of people in venue | Average # burning cigs | Average active smoker density* | Average $PM_{2.5}$ level ($\mu g/m^3$) |
|---|---|---|---|---|---|---|
| Smoke-free Restaurants | 8 | 268 | 18 | 0.00 | 0.00 | 12 |
| Bowling Alleys | 3 | 3740 | 83 | 7.92 | 0.21 | 74 |
| Casinos | 9 | ** | ** | ** | ** | 92 |
| Smoking Restaurants | 15 | 618 | 41 | 4.06 | 0.60 | 96 |
| Bars | 16 | 588 | 79 | 6.57 | 1.07 | 339 |

* Average number of burning cigarettes per $100m^3$

** Due to the massive size and large number of people in the casinos it was not possible to determine room volumes, people counts or burning cigarette counts

Figure 2 shows the average indoor air pollution levels, as determined by $PM_{2.5}$ levels, in the 5 types of locations as well as the average $PM_{2.5}$ level in outdoor air in New Jersey. Ten of the thirteen counties in this study had at least one outdoor $PM_{2.5}$ monitoring site using the EPA's Federal Reference Method for measuring $PM_{2.5}$. The year-to-date average $PM_{2.5}$ level from each of these sites, as of November 10th, 2005, was found at **http://www.epa.gov/air/data/** and they were averaged to determine the average outdoor $PM_{2.5}$ level as a comparison for this study. As seen in Figure 2, the average indoor $PM_{2.5}$ concentration in the 8 smoke-free sites (12 $\mu g/m^3$) was the same as the average outdoor concentration in New Jersey.

**Figure 2.** Fine Particle Air Pollution in All New Jersey Venues by Type of Venue, August 18, 2005 to September 27, 2005




[i] p=0.014 for comparison of smoke-free restaurants to bowling centers and p<0.001 for comparison of smoke-free restaurants to smoking casinos, smoking restaurants, and smoking bars (Mann Whitney U-test)

* Some with alcoholic beverage service, some with bars

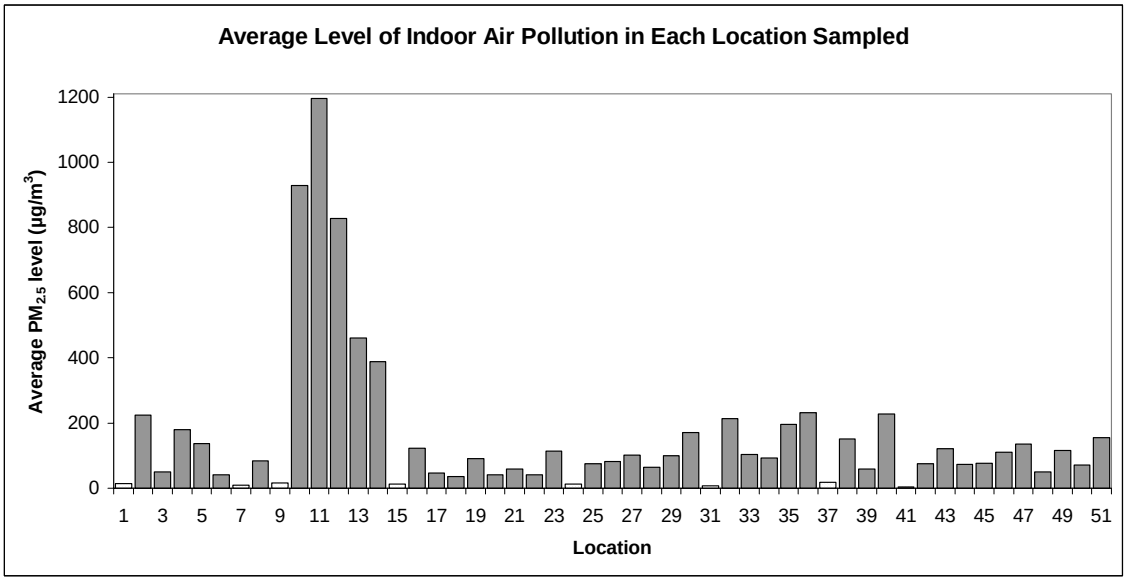
** Based on the 2005 average $PM_{2.5}$ level as of 11/10/2005 in the 10 of 13 NJ counties in this study with outdoor EPA monitoring sites http://www.epa.gov/air/data/

*** Some with food service

Compared to both the smoke-free sites in this study and outdoor air in New Jersey, the bowling centers had 6.2 times more air pollution, the casinos had 7.7 times more air pollution, the smoking restaurants had 8.0 times more air pollution, and the bars had 28.0 times more air pollution. The differences in air quality between the smoke-free sites and bowling centers ($p=0.014$), casinos ($p<0.001$), smoking restaurants ($p<0.001$), and bars ($p<0.001$) are all statistically significant according to the Mann Whitney U-Test.

Figure 3 shows the average indoor air pollution level in each of the 51 locations tested. The smoke-free sites (1, 7, 9, 15, 24, 31, 37, and 41) have white bars but are difficult to see because the level of pollution in these places is so close to zero. While the average level in all of the smoking places is 15 times higher than in the smoke-free places (see Figure 1), Figure 3 shows that many places were in fact between 30 and 100 times more polluted than smoke-free indoor sites.

**Figure 3.** Average Level of Indoor Air Pollution in Each Location Visited, New Jersey, August 18 to September 27, 2005



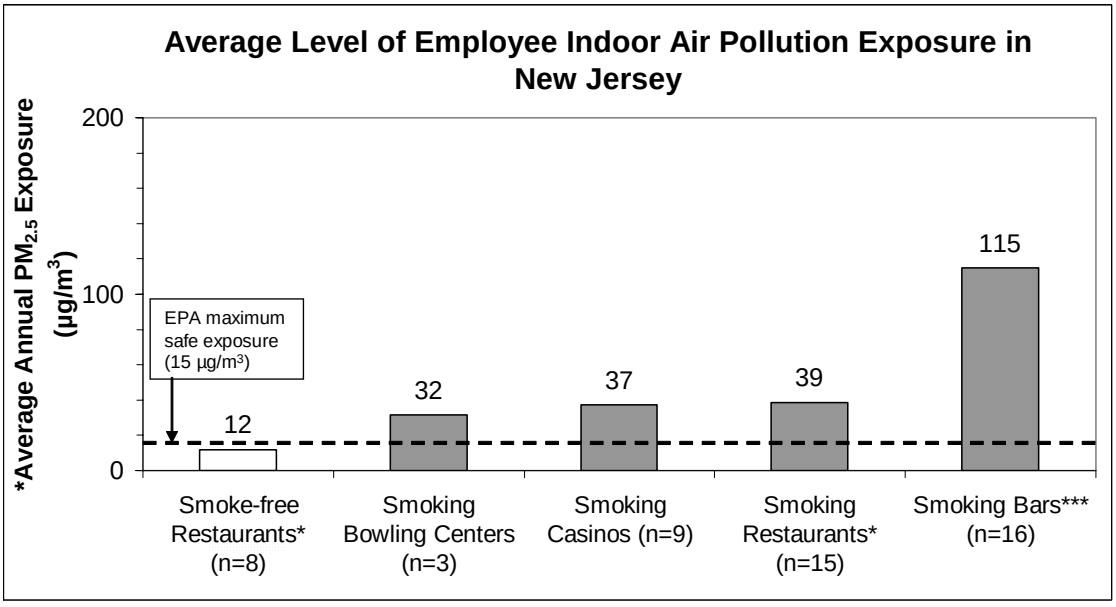

The actual real-time plots showing the level of indoor air pollution in each venue sampled are presented in Figures 5 through 13, starting on page 12. Results from the real-time $PM_{2.5}$ plots throughout the duration of sampling reveal the following three general trends: 1) much higher levels of indoor air pollution are observed in venues where smoking is permitted; 2) low background levels are observed in the time between venues allowing smoking; and 3) peak exposure levels in some venues can reach levels far in excess of the average recorded level.

## Discussion

The EPA cited over 80 epidemiologic studies in creating a particulate air pollution standard in 1997[vii]. 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 65 $\mu g/m^3$ 24-hour exposure. In order to compare the findings in this study with the annual EPA $PM_{2.5}$ exposure standard, it was assumed that a full-time employee in the locations sampled that allow smoking works 8 hours, 250 days a year, is exposed to 184 $\mu g/m^3$ (the average level in all sites allowing smoking) on the job, and is exposed only to background particle levels of 12 $\mu g/m^3$ during non-work times. For a full-time employee their average annual $PM_{2.5}$ exposure would be 51 $\mu g/m^3$. The EPA average annual $PM_{2.5}$ limit is exceeded by 3.4 times due to their occupational exposure.

Figure 4 shows the average annual exposures of employees in each of the 5 types of locations in this study as compared to the EPA annual $PM_{2.5}$ exposure limit of 15 $\mu g/m^3$. Employees in bowling centers are exposed to 2.1 times the EPA maximum safe exposure level, casino employees are exposed to 2.5 times the limit, employees in smoking restaurants are exposed to 2.6 times the limit and bar employees are exposed to 7.7 times the safe limit. Based on the latest scientific evidence, the EPA staff currently proposes even lower $PM_{2.5}$ standards to adequately protect the public health,[viii] making the high $PM_{2.5}$ exposures of people in smoking environments even more alarming.

**Figure 4.** Annual Employee Air Pollution Exposure in All New Jersey Locations August 18, 2005 to September 27, 2005




* Assumes an employee works eight hours, 250 days a year, and is only exposed to background particle levels (12 $\mu g/m^3$) during non-work times

Previous studies have evaluated air quality by measuring the change in levels of respirable suspended particles (RSP) between smoke-free venues and those that permit

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.[ix] 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.[x] 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 even a 58% reduction in locations where only SHS from an adjacent room was observed at baseline.[xi] 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 smoke-free air laws, even though compliance with the laws was less than 100%.[xii]

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 smoke-free workplace law was implemented in California[xiii], 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 smoke-free ordinance was in effect.[xiv] The effects of even brief (minutes to hours) passive smoking on the cardiovascular system are often nearly as large (averaging 80% to 90%) as chronic active smoking. 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.[xii]

## Conclusions

Locations allowing indoor smoking are significantly more polluted than indoor smoke-free sites and than outdoor air in New Jersey, with levels of pollution in excess of EPA standards. This study demonstrates that workers and patrons in New Jersey are exposed to harmful levels of secondhand smoke, a known human carcinogen and toxin. Policies that prohibit smoking in public worksites dramatically reduce secondhand smoke exposure and improve worker and patron health.

## Acknowledgments

Support for this work was provided by the Flight Attendant Medical Research Institute and the American Cancer Society of New York and New Jersey.

Figure 5

# New Jersey Air Monitoring Study
## August 18th 2005

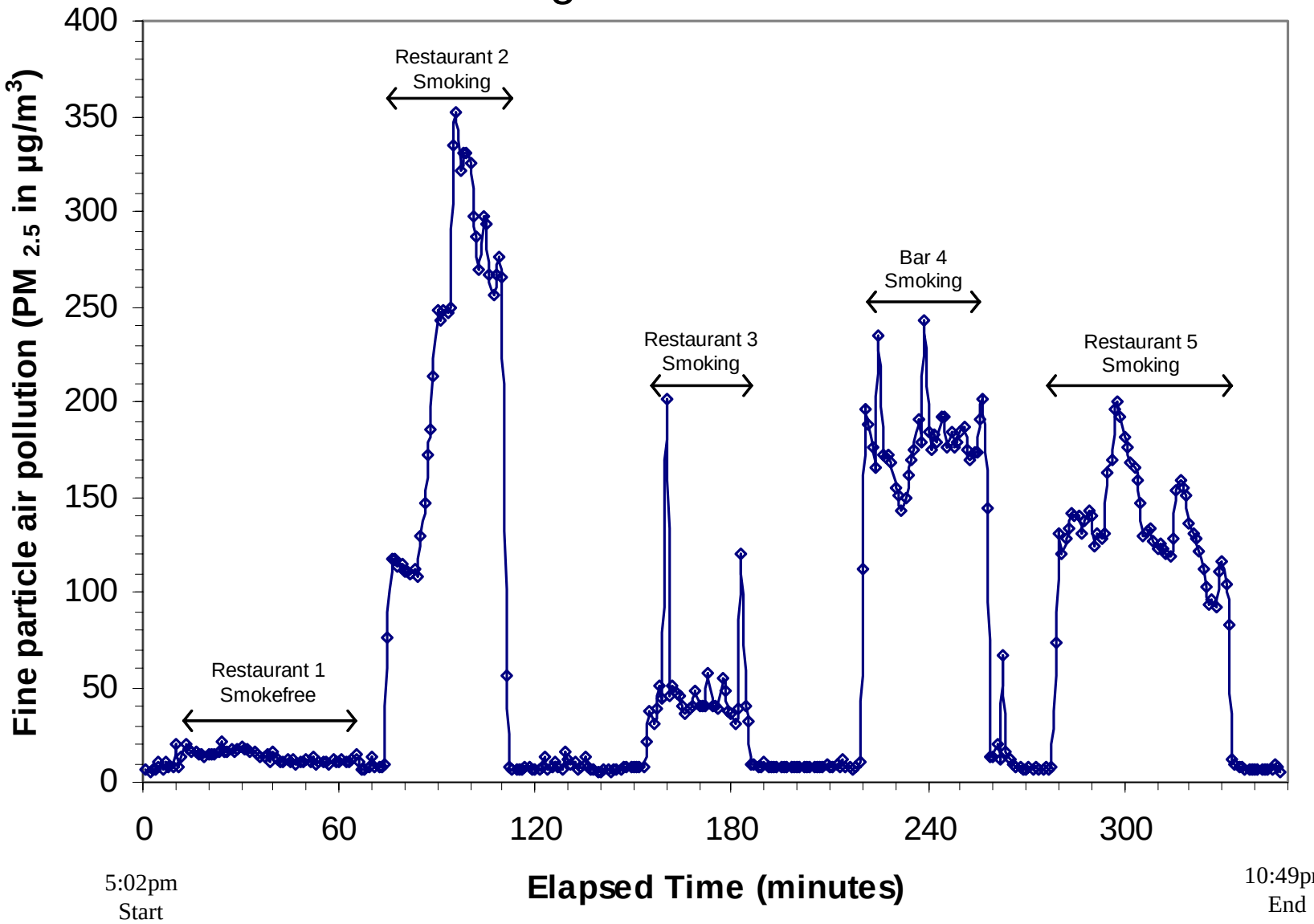


Figure 6

# New Jersey Air Monitoring Study
## August 26th 2005

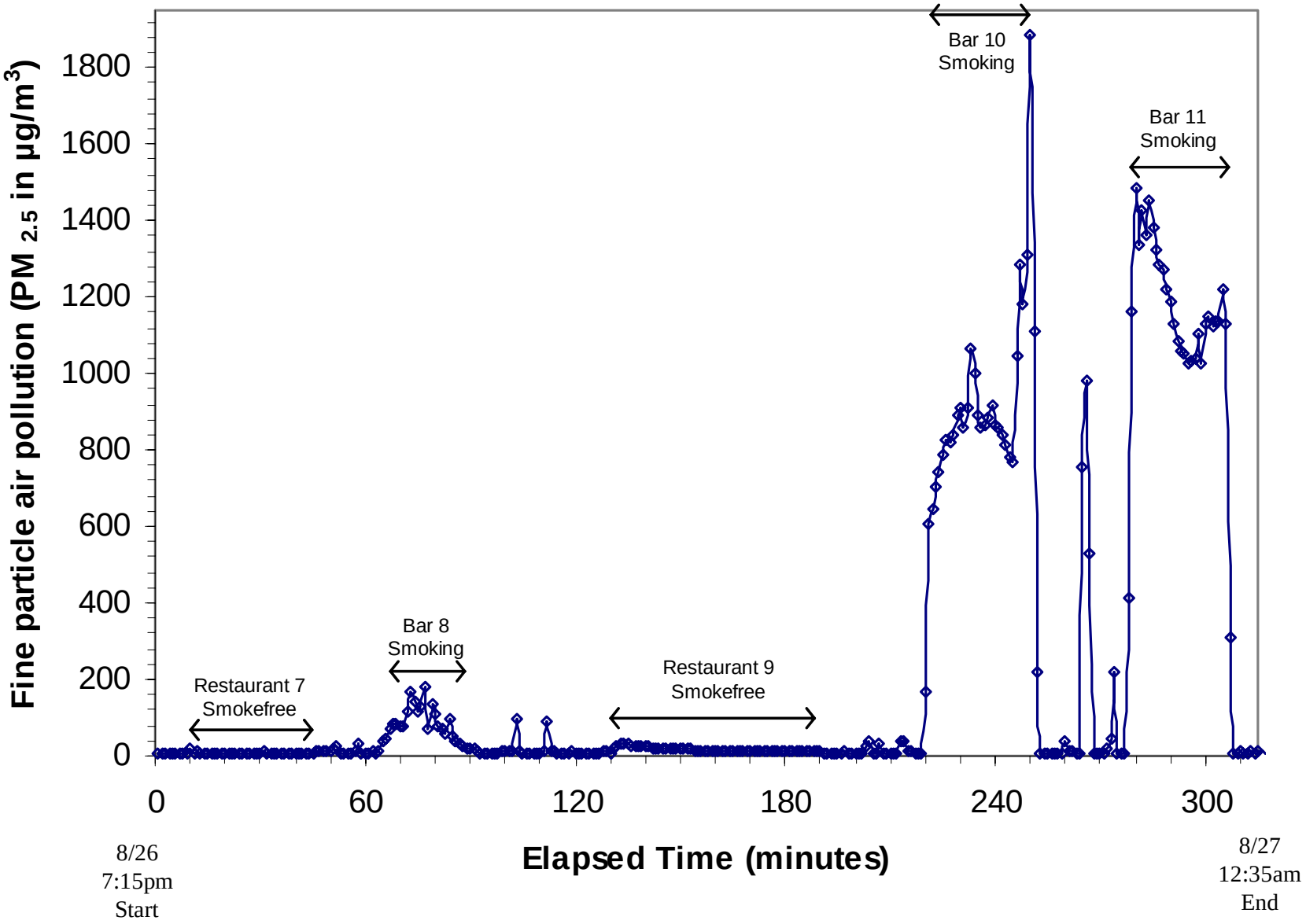


Figure 7

# New Jersey Air Monitoring Study
# August 27th and 29th 2005

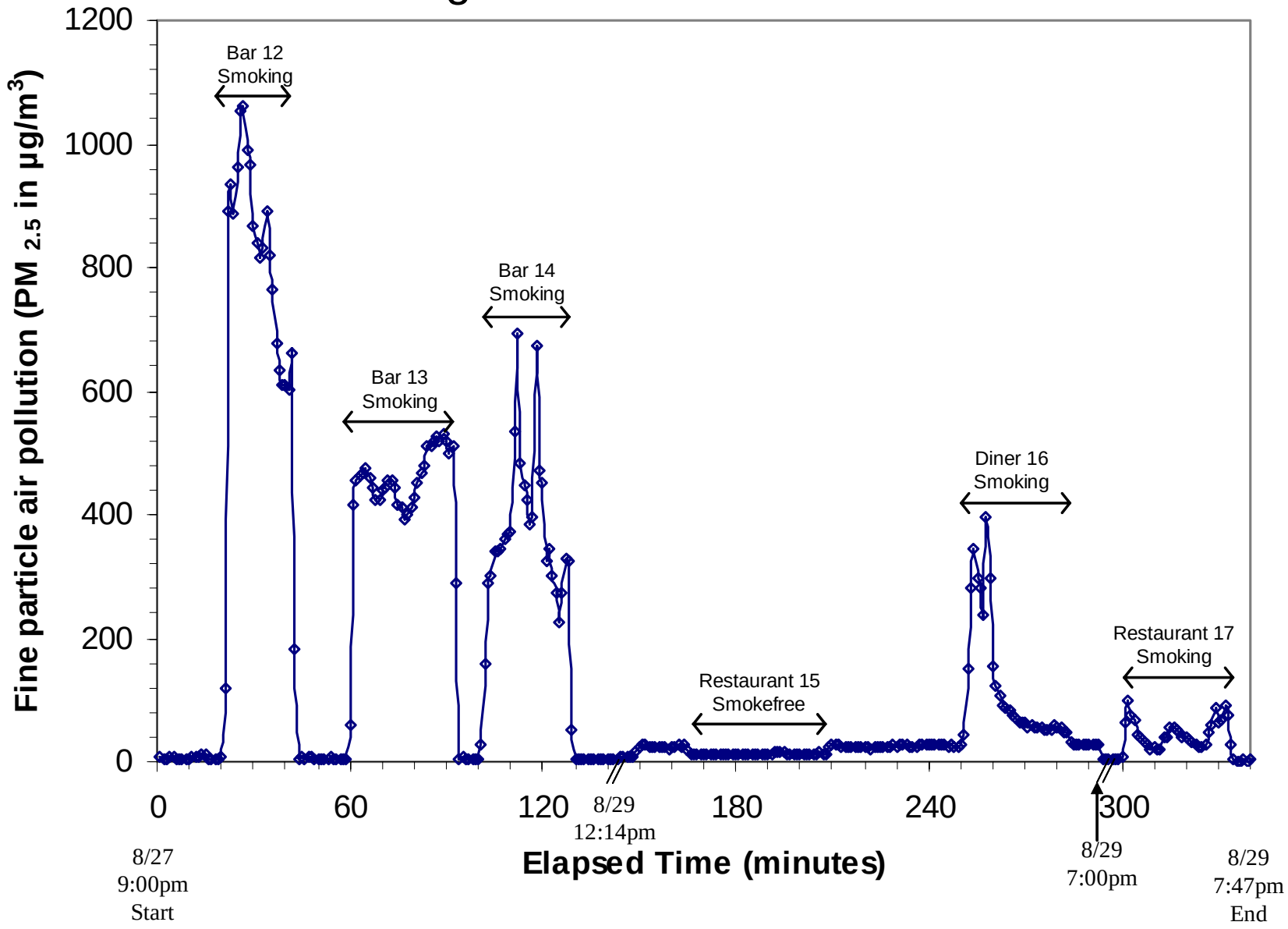


Figure 8

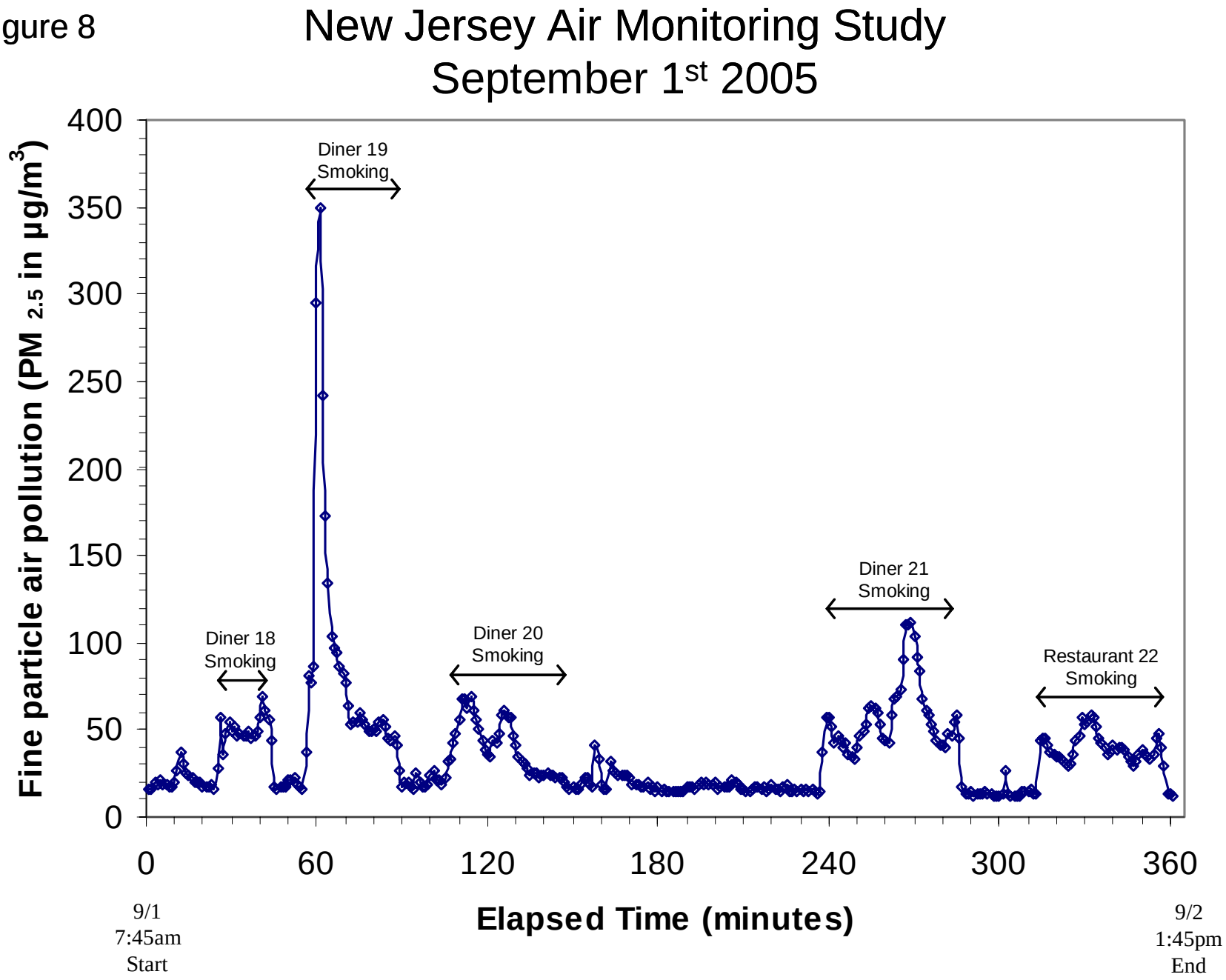

New Jersey Air Monitoring Study
September 1st 2005
Fine particle air pollution (PM 2.5 in µg/m3)
400
350
300
250
200
150
100
50
0
Diner 19 Smoking
Diner 18 Smoking
Diner 20 Smoking
Diner 21 Smoking
Restaurant 22 Smoking
0
60
120
180
240
300
360
Elapsed Time (minutes)
9/1 7:45am Start
9/2 1:45pm End

Figure 9

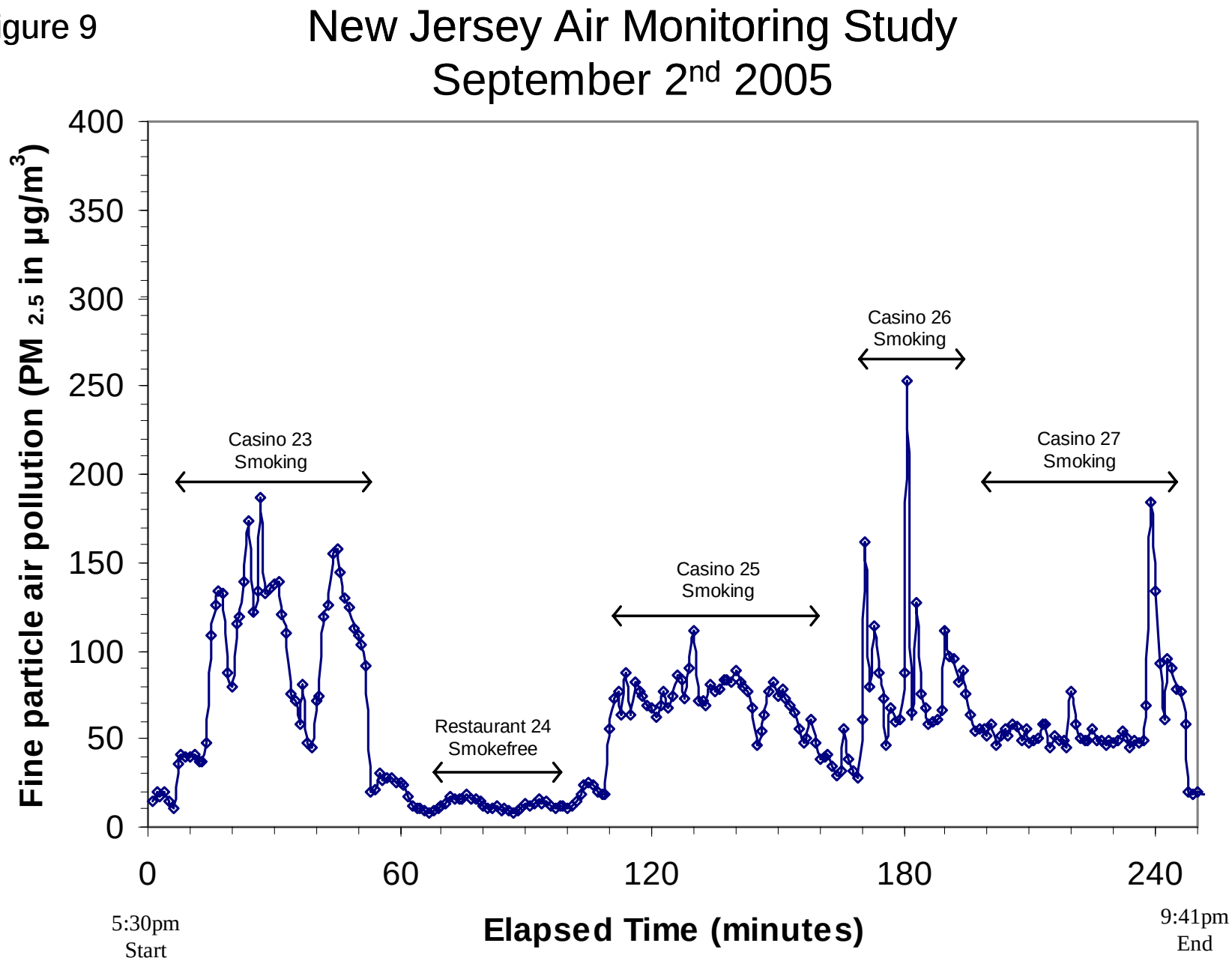

New Jersey Air Monitoring Study
September 2nd 2005
Fine particle air pollution (PM 2.5 in µg/m3)
400
350
300
250
200
150
100
50
0
Casino 23 Smoking
Restaurant 24 Smokefree
Casino 25 Smoking
Casino 26 Smoking
Casino 27 Smoking
0
60
120
180
240
5:30pm Start
Elapsed Time (minutes)
9:41pm End

Figure 10

# New Jersey Air Monitoring Study
## September 6th 2005

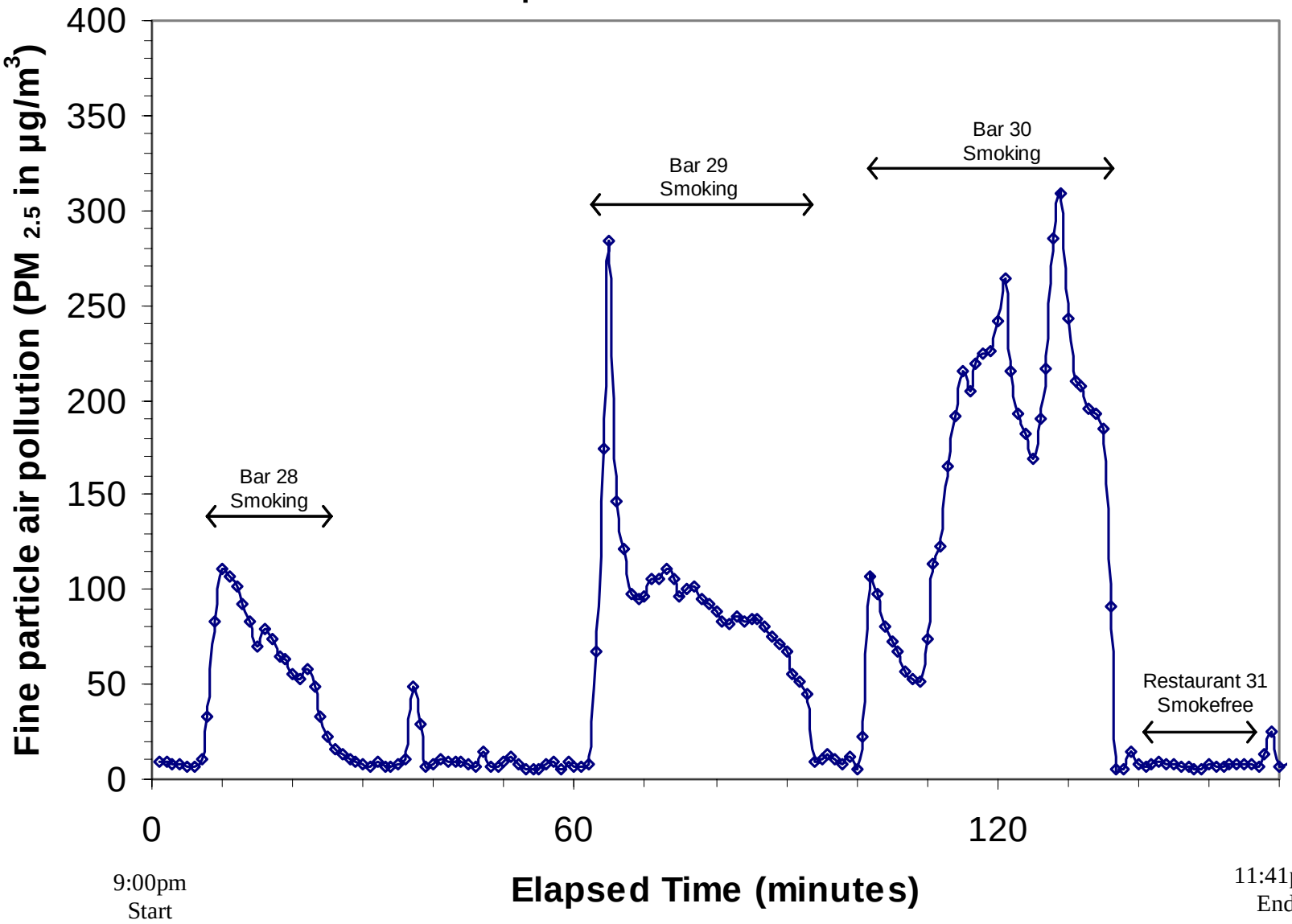


Figure 11

# New Jersey Air Monitoring Study
# September 8th and 9th 2005

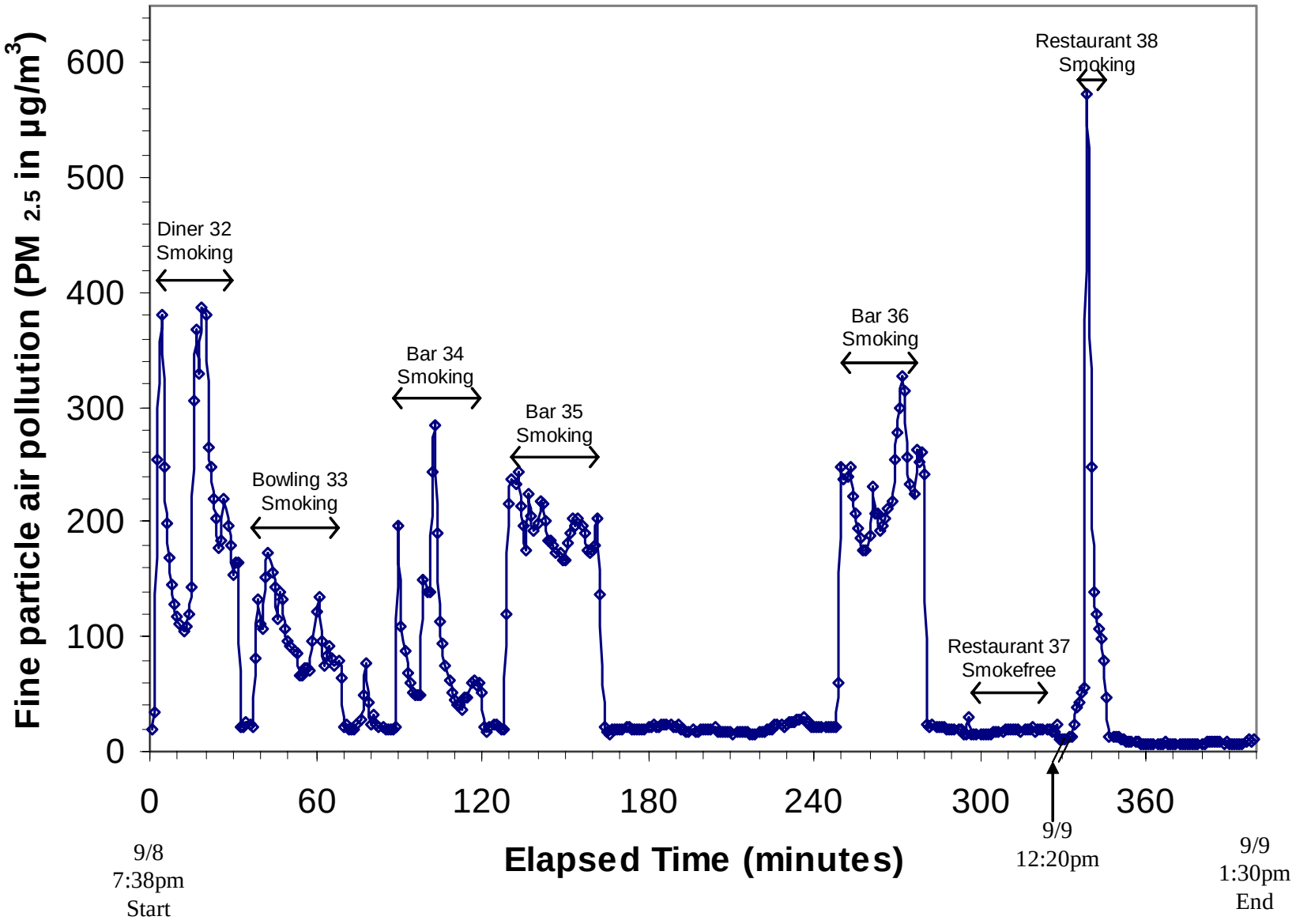


Figure 12

# New Jersey Air Monitoring Study
# September 10th 2005

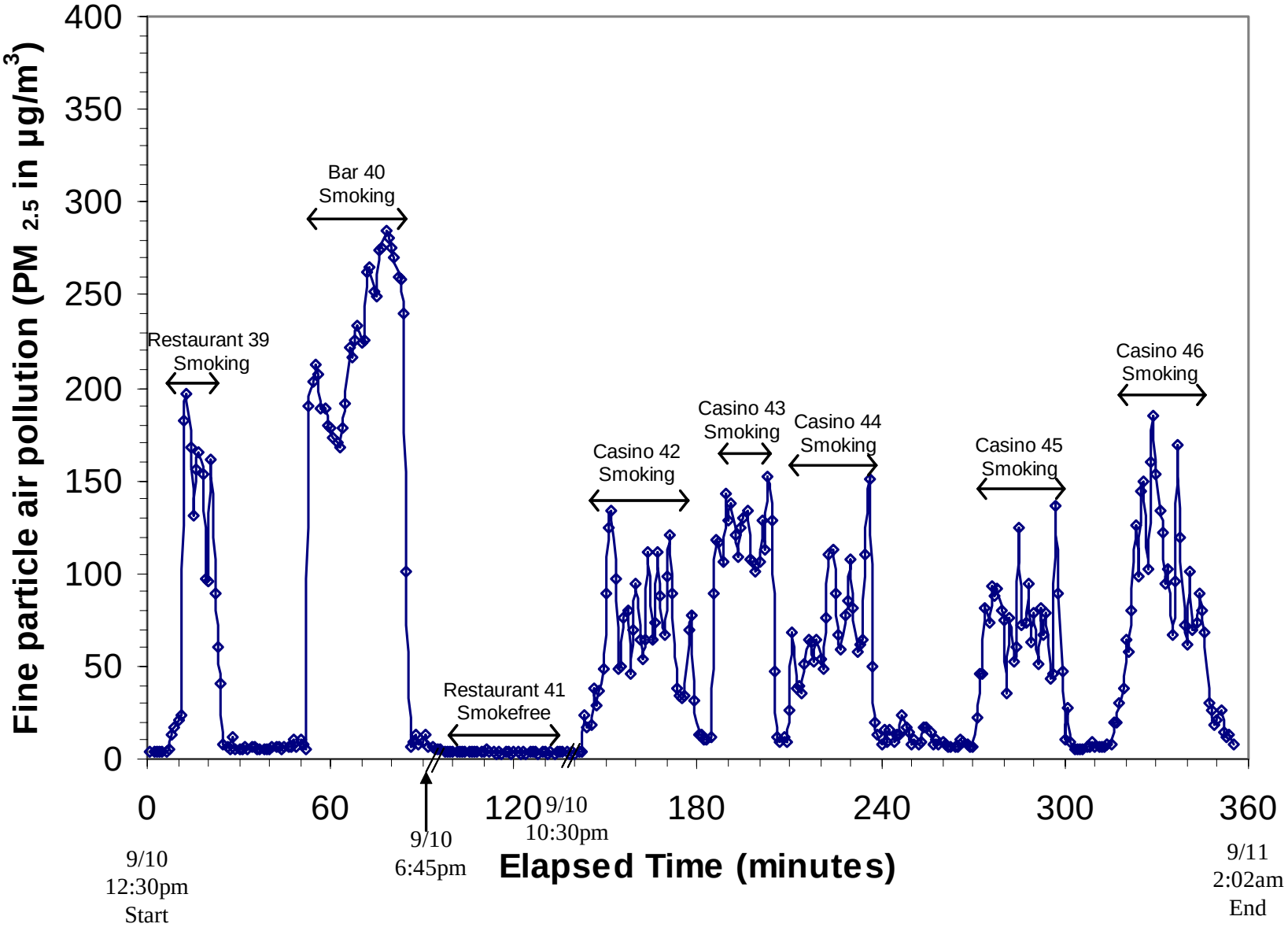
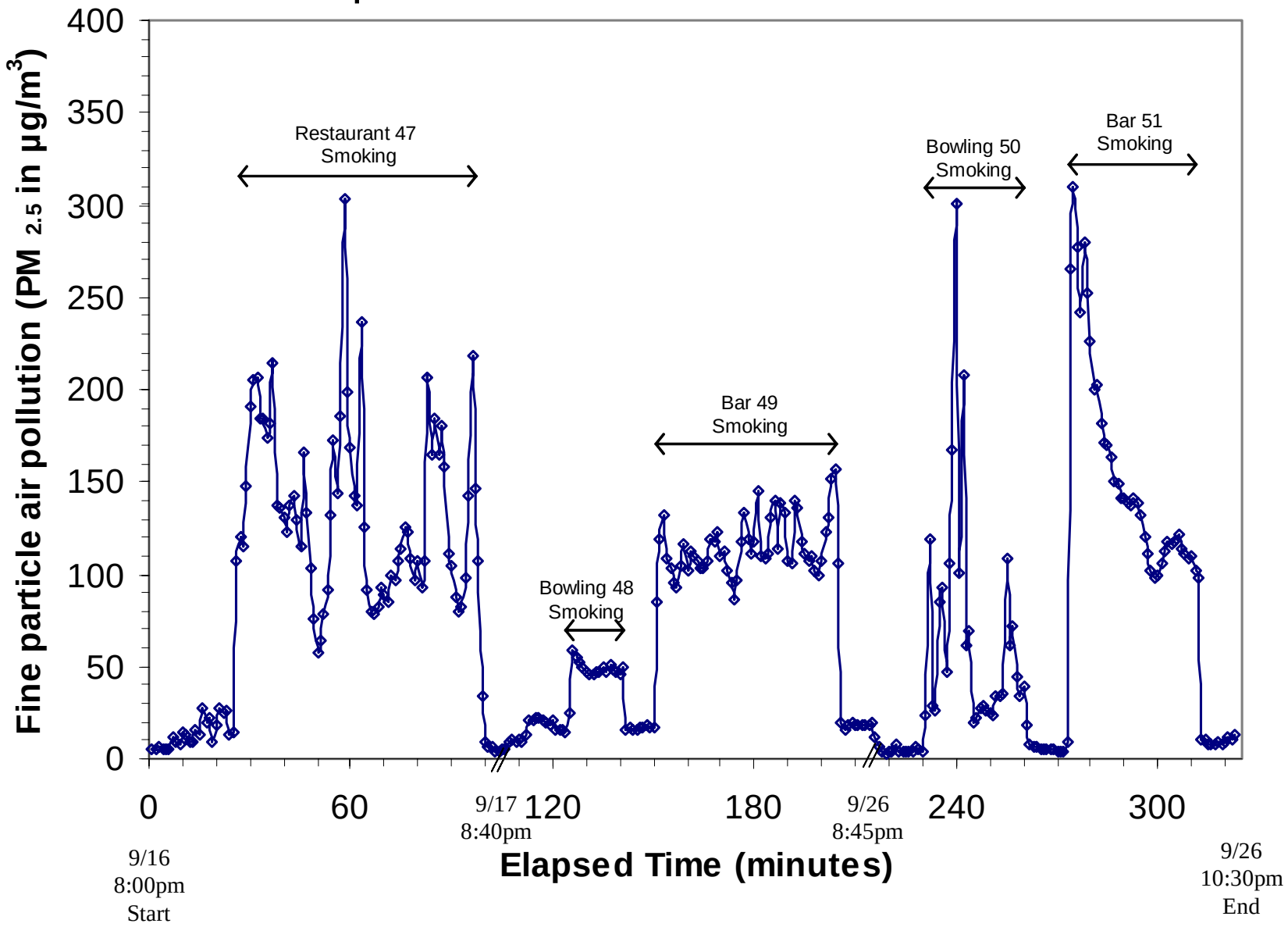


Figure 13

# New Jersey Air Monitoring Study
# September 16th, 17th and 26th 2005



## References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