Asthma in Pittsburgh and Allegheny County, Current Information and Future Directions

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PITT PUBLIC HEALTH

Objectives

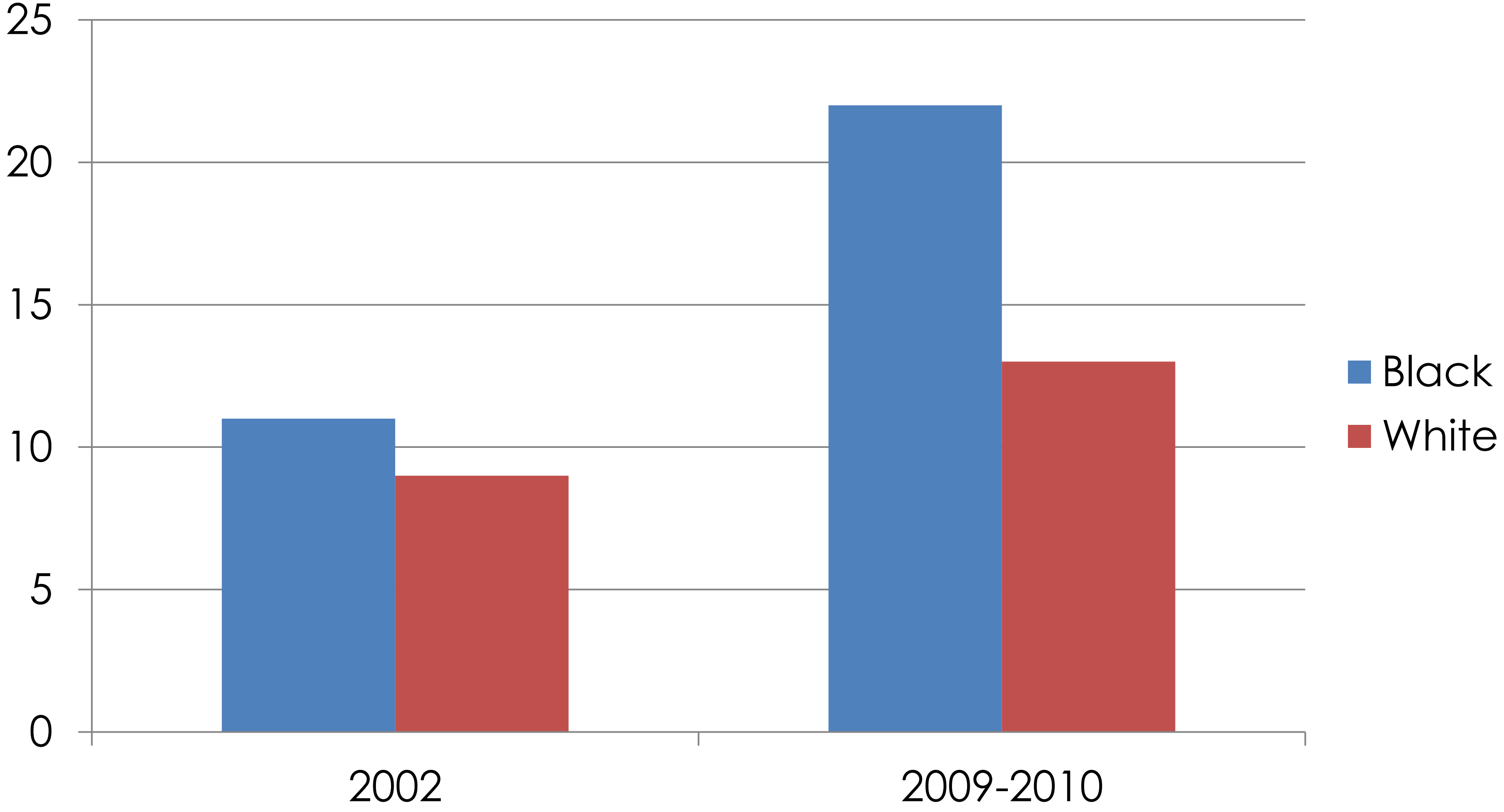
- The increasing prevalence of asthma
- The local importance of asthma
- The history of asthma/air pollution epidemiology
- The impact of air pollution on asthma
- The local impact of air pollution on asthma

The burden of asthma

- In 2009, 25 million people, or 8% of the population, had asthma.
  - Compared to 2001, when 20 million, or 7%
  - Asthma rates rose the most among black children, an almost 50% increase

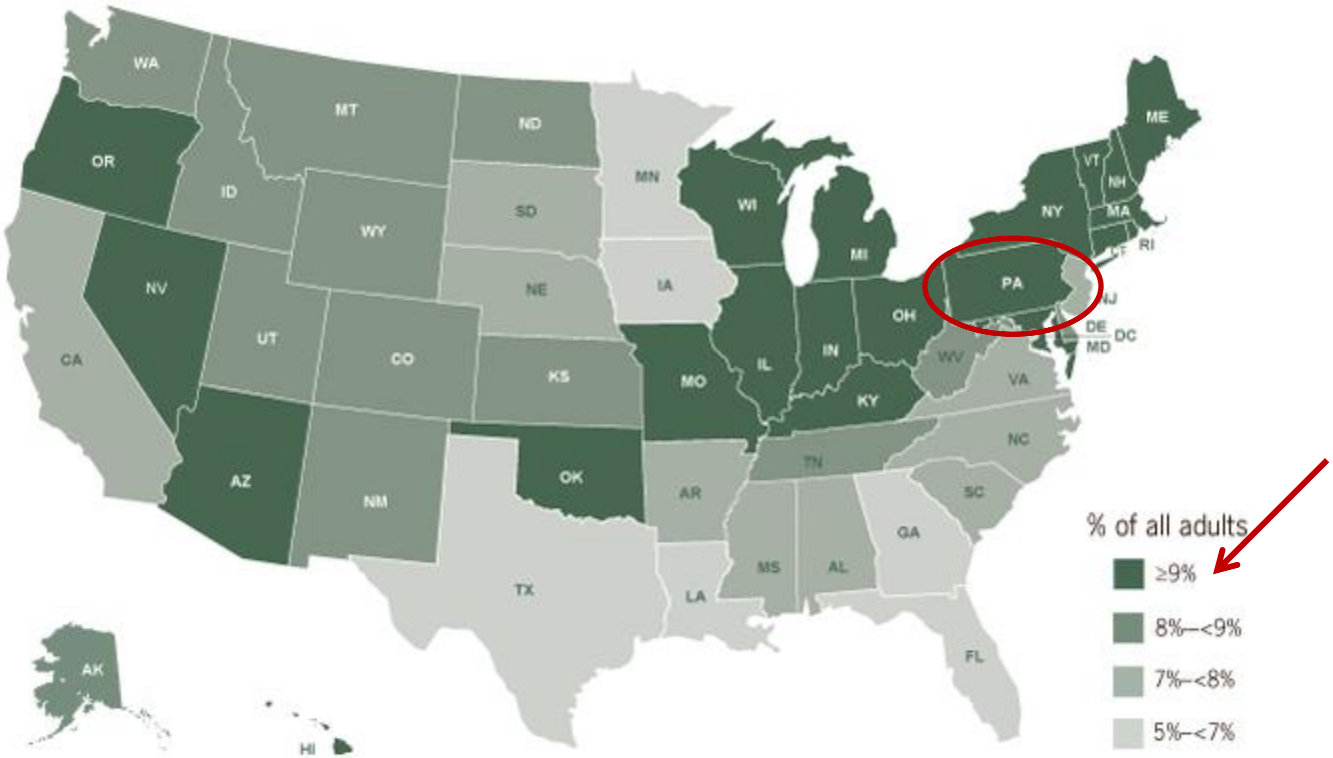
CDC Vital Signs “Asthma in the US,” May 2011

Asthma in Allegheny County Adults by Race, 2002 and 2009-2010



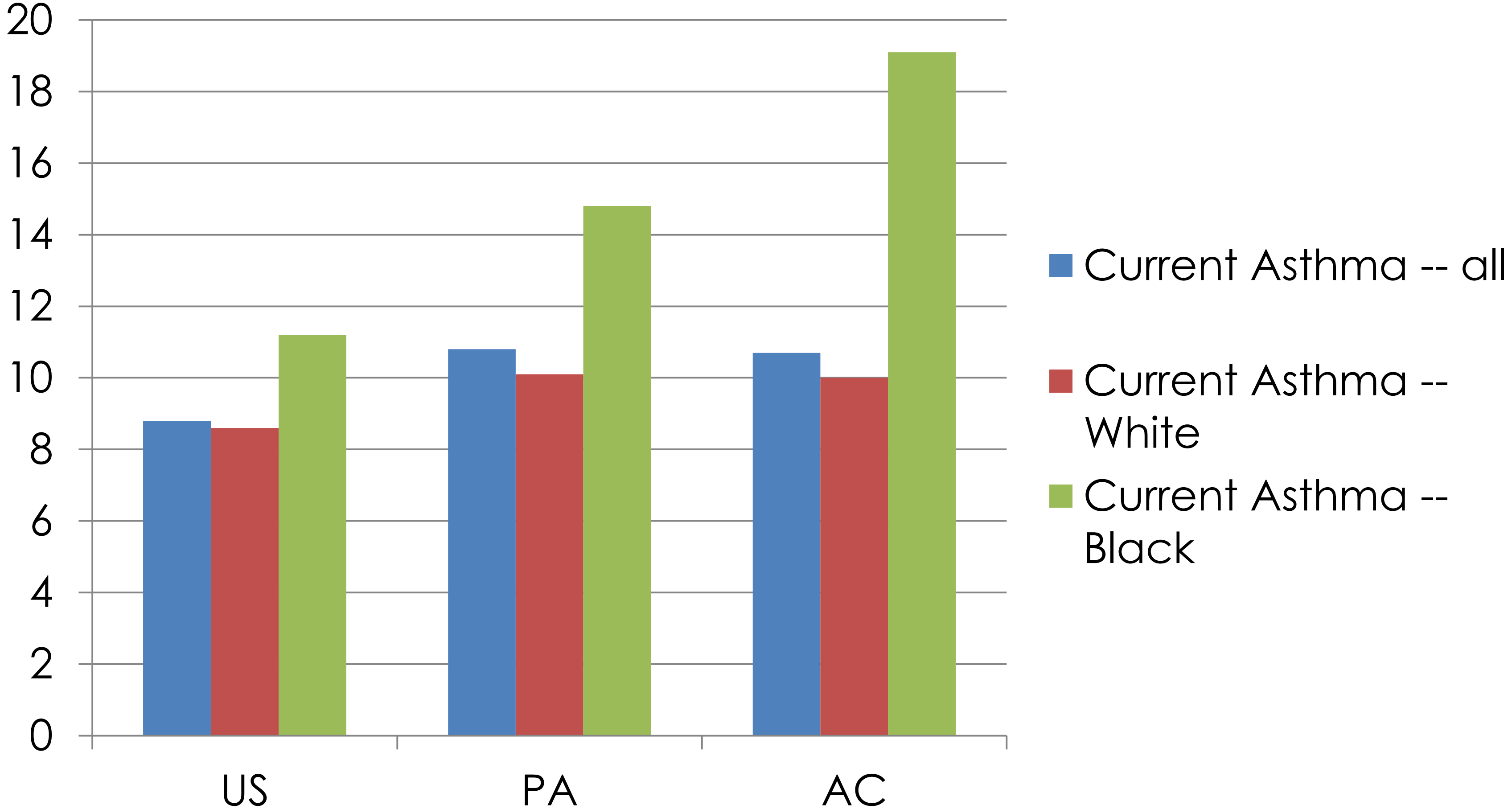
Adapted from AC BRFSS, published 2012

Adults with asthma in the US, 2009



SOURCE: Behavioral Risk Factor Surveillance System, 2009

Comparison of National and Local Asthma Rates by Race, 2010



ASTHMA & AIR POLLUTION

PARTICLES IN THE AIR LIKE DUST, DIRT, SOOT, AND SMOKE ARE CALLED

PARTICULATE MATTER & CAN CAUSE

- Increased hospital visits
- Worsened asthma symptoms
- Adverse birth outcomes
- Breathing problems
- Decreased lung growth in kids
- Lung cancer
- Early death

GROUND-LEVEL OZONE

Forms when pollutants from cars and trucks, power plants, factories, and other sources come in contact with each other in heat and sunlight. Factors such as weather conditions and intensity of sunlight also play a part in how ozone is formed. Ground-level ozone is one of the biggest parts of smog, and it is usually worse in the summer months.

WHO'S AT RISK?

People with heart or lung disease, infants, children with asthma or who spend a lot of time outdoors, older adults, and active people of all ages who exercise or work hard outdoors

WHAT CAN YOU DO?

- Check the daily air quality forecast via newspaper, TV, radio, or online at http://airnow.gov to learn when particle levels are unhealthy

- Reduce the amount of time outside when pollution is high

- Plan outdoor activities when ozone levels are lower, usually in the morning and evening

- Exercise away from roads and highways. Particle pollution is usually worse near these areas

- Do easier outdoor activities, such as walking instead of running or using a riding lawn mower instead of a push mower

LEARN MORE

www.cdc.gov/ephtracking

CDC

Criteria Pollutants

- Ozone
- Nitrogen Oxides
- Sulfur Oxides
- Particulate Matter
- Carbon Monoxide
- Lead

John Balmes

post-gazette.com
Pittsburgh Post-Gazette
April 26, 2013 2:48 pm

Report: Pittsburgh's air quality improving, but still among most polluted

April 24, 2013 12:17 am

By Lexi Belculfine / Pittsburgh Post-Gazette

While the air in Pittsburgh is the cleanest it's ever been, the American Lung Association still ranks the city among the United States' most-polluted metropolises.

Pittsburgh is one of two metro areas outside of California to rank among the top 25 most polluted by ozone smog and by soot, formally called long- and short-term particle pollution, according to the American Lung Association's State of the Air 2013 report released today.

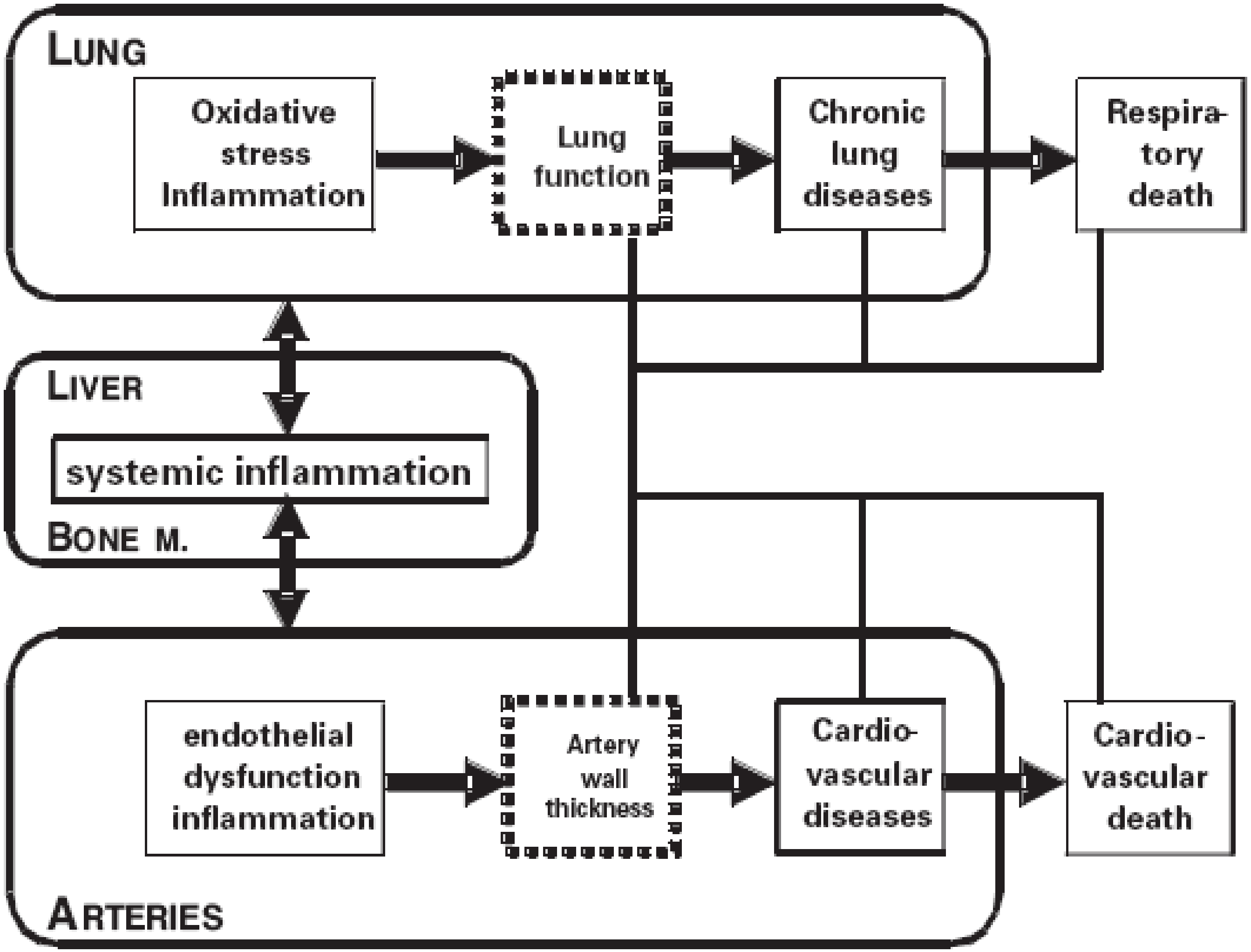
Pittsburgh was ranked 7th in short-term particle pollution, 8th in year-round particle pollution and 24th among the ozone-polluted, the lung association said.

But the quality of air has improved in each category since last year, as "the air quality in Pittsburgh, and nationwide, continues the long-term trend to much healthier air," the group said in a press release.

Potential biological mechanism of PM effects

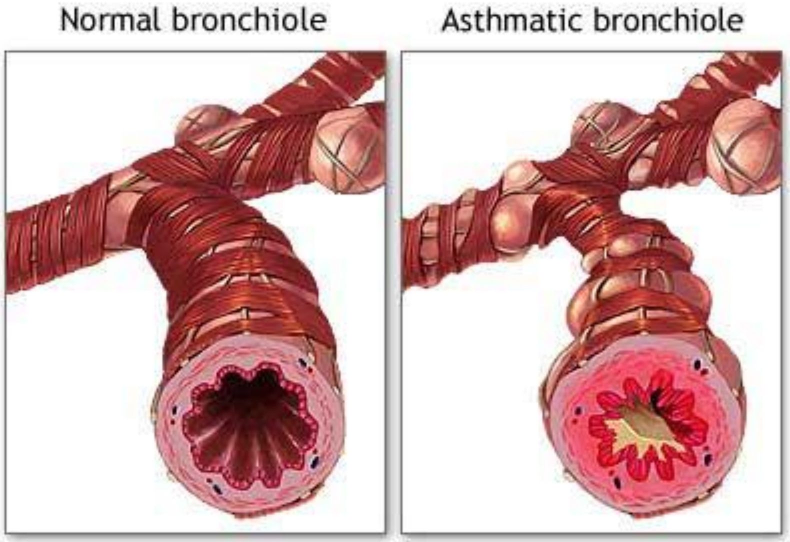
Figure 1

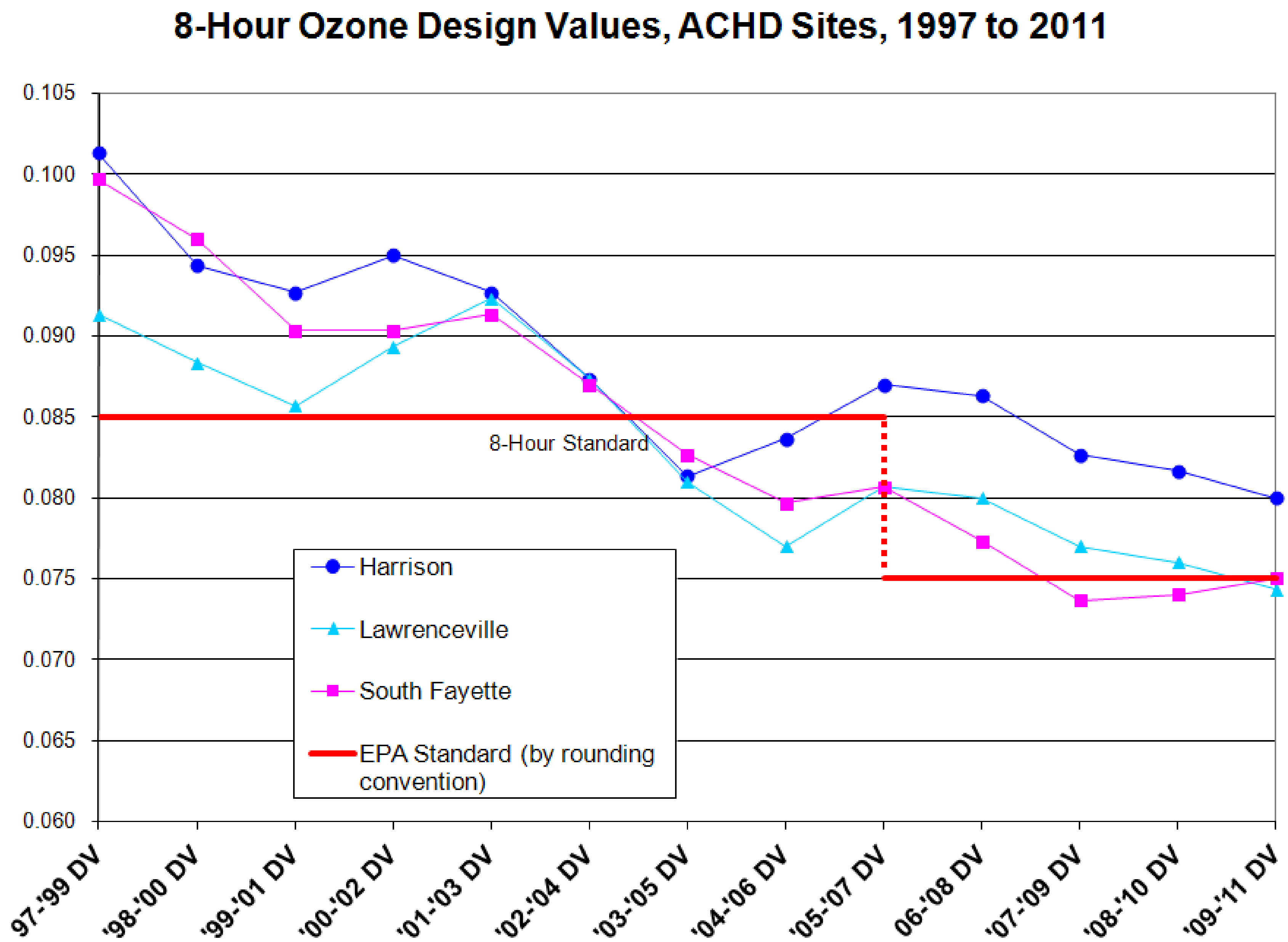
Model of the interrelated pulmonary, systemic, and vascular chronic inflammatory responses to air pollution. Lung function and artery wall thickness are examples of markers of the continuous chronic process from health to disease. (Thin lines denote correlations established in epidemiological studies).



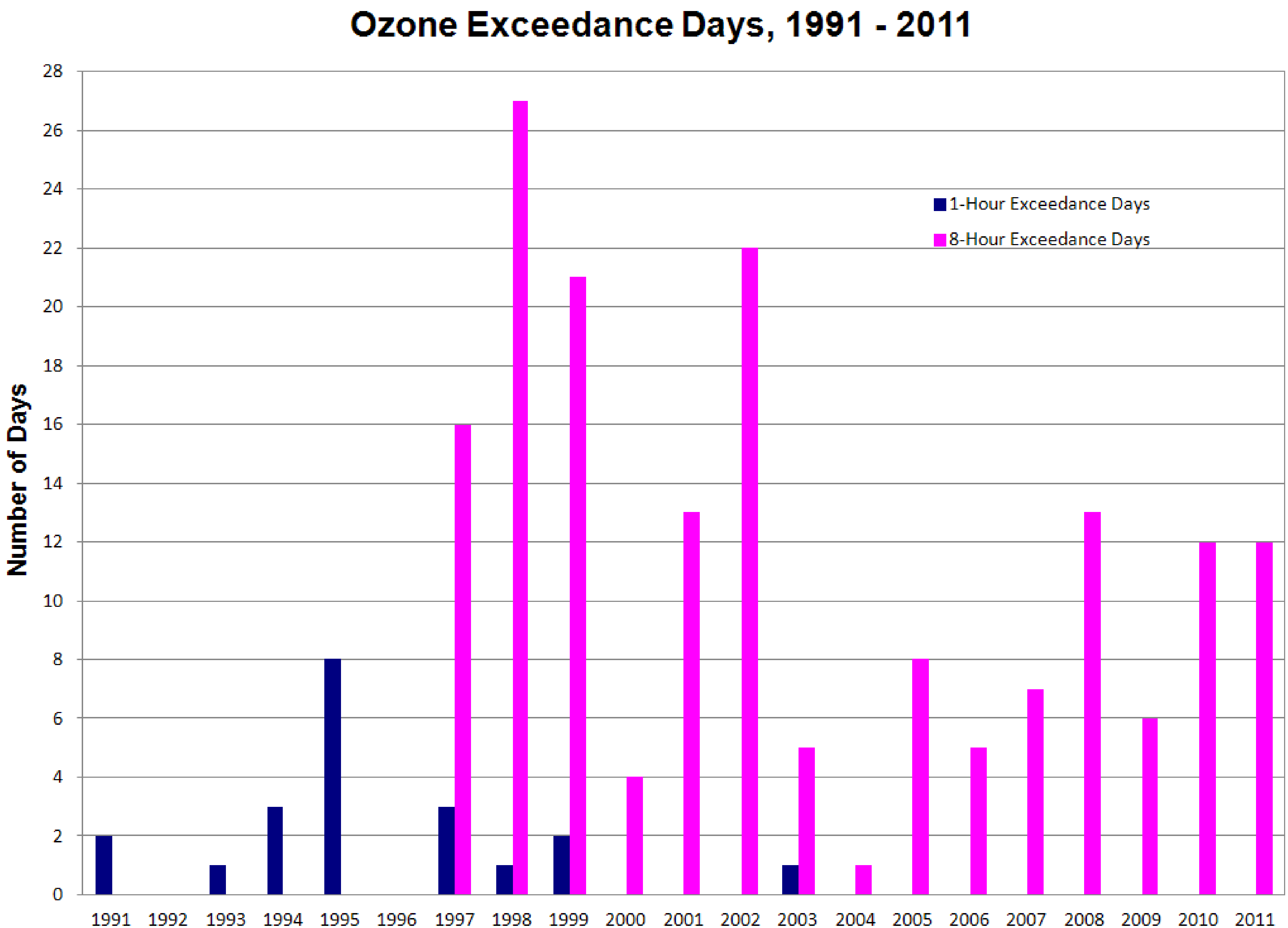
Mechanisms of Ozone Toxicity

- Direct oxidation
- Free radical formation
- Lipid peroxidation
- Secondary inflammation/repair





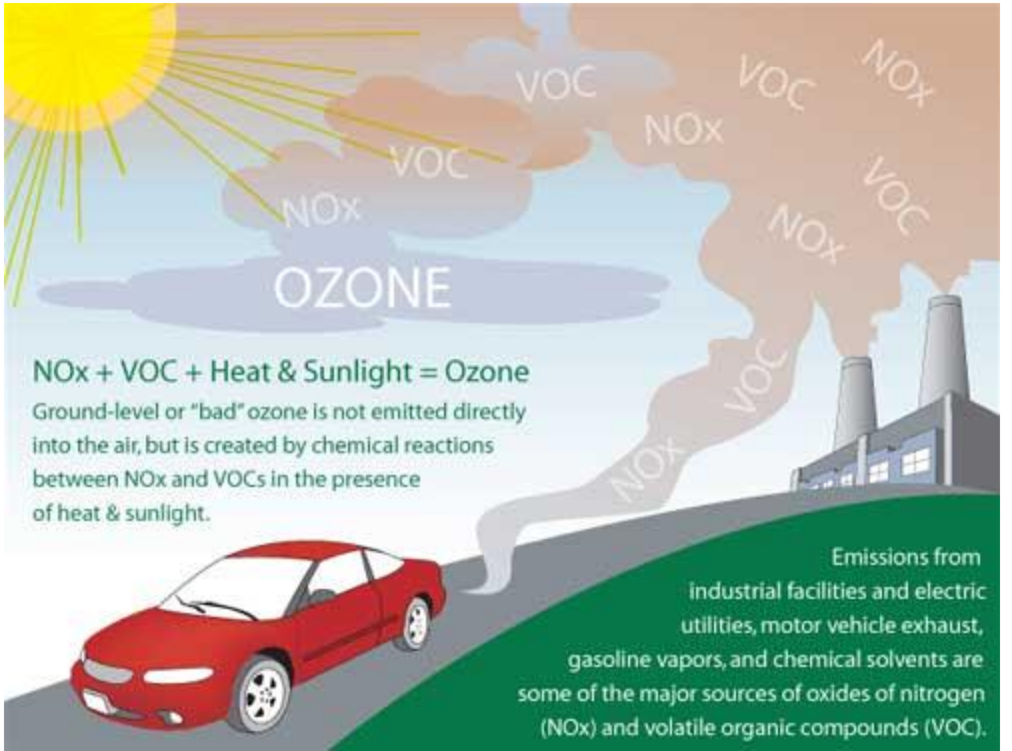
8-Hour Ozone Design Values, ACHD Sites, 1997 to 2011
0.105
0.100
0.095
0.090
0.085
0.080
0.075
0.070
0.065
0.060
8-Hour Standard
Harrison
Lawrenceville
South Fayette
EPA Standard (by rounding convention)
97-'99 DV
'98-'00 DV
'99-'01 DV
'00-'02 DV
'01-'03 DV
'02-'04 DV
'03-'05 DV
'04-'06 DV
'05-'07 DV
06-'08 DV
'07-'09 DV
'08-'10 DV
'09-'11 DV

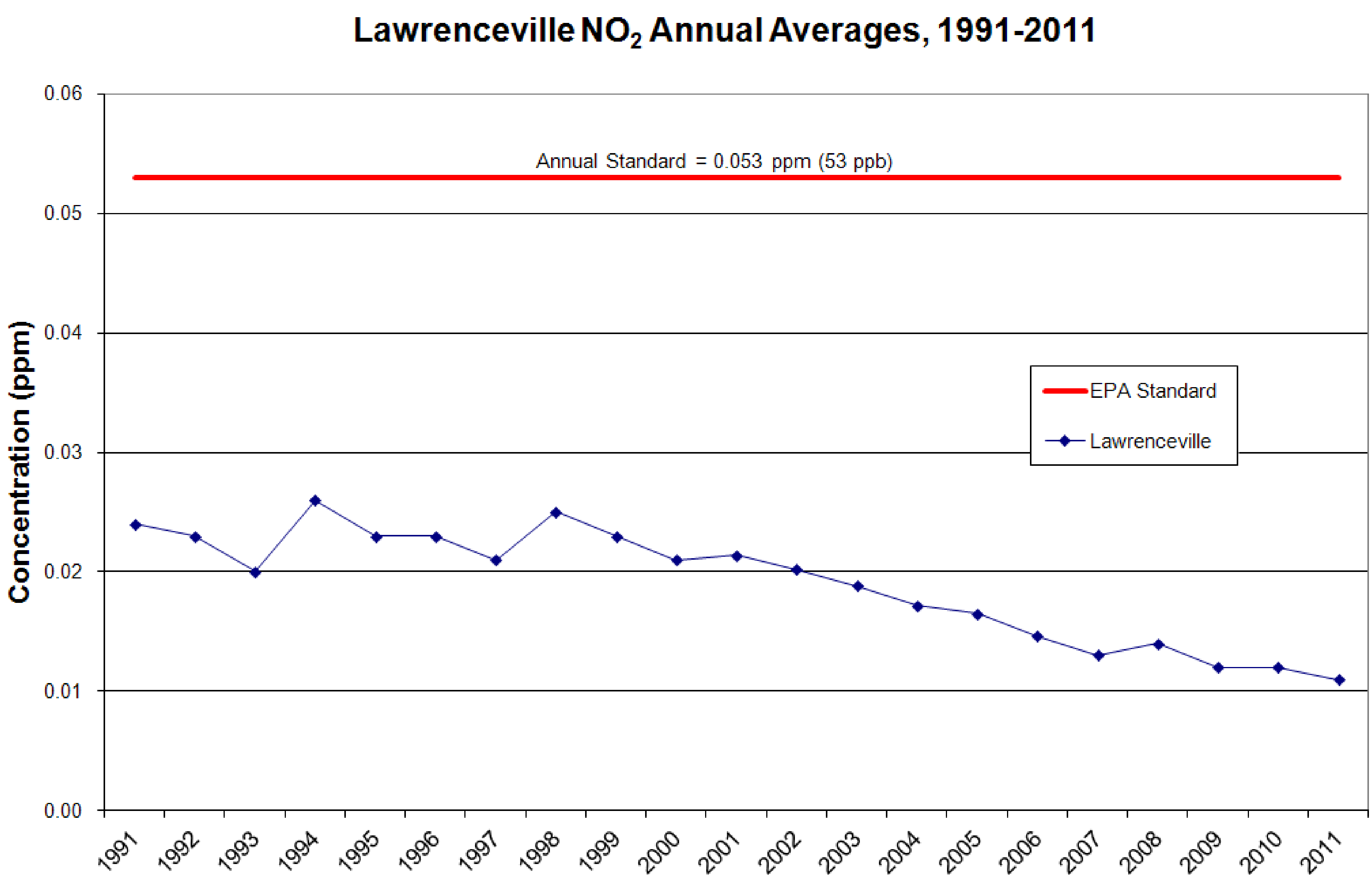


Ozone Exceedance Days, 1991 - 2011
Number of Days
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
1-Hour Exceedance Days
8-Hour Exceedance Days

Nitrogen Oxide

- NO_2 not as potent of an oxidant as ozone
- NO_2 reacts with H_2O to form HNO_3

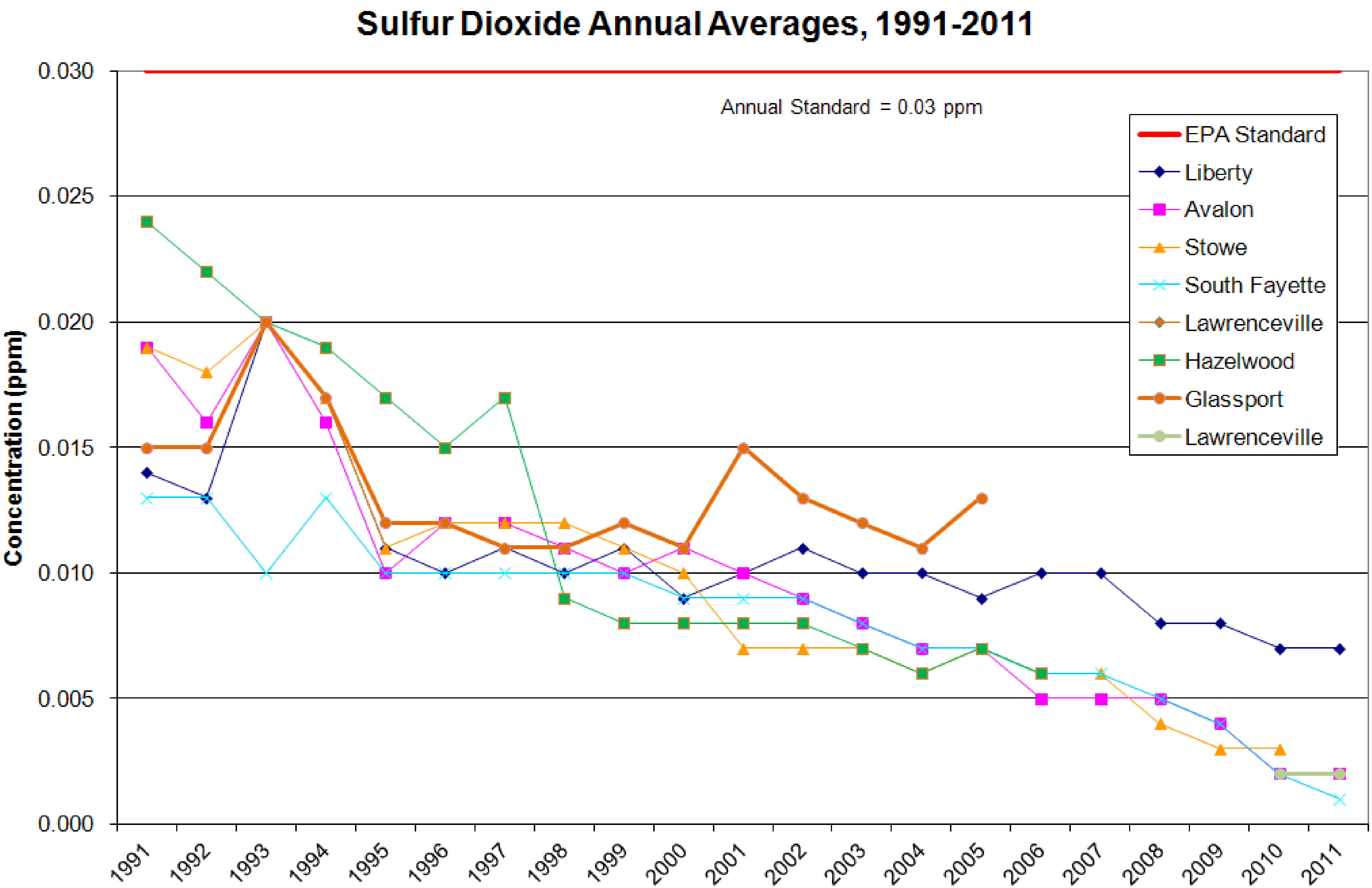




Lawrenceville NO2 Annual Averages, 1991-2011
Annual Standard = 0.053 ppm (53 ppb)
EPA Standard
Lawrenceville
Concentration (ppm)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

Sulfur Dioxide

- The NAAQS for SO_2 allows for relatively high short-term peak exposures.
- People with asthma are not protected from exacerbations caused by brief exposures.



Sulfur Dioxide Annual Averages, 1991-2011
Annual Standard = 0.03 ppm
Concentration (ppm)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
EPA Standard
Liberty
Avalon
Stowe
South Fayette
Lawrenceville
Hazelwood
Glassport
Lawrenceville
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

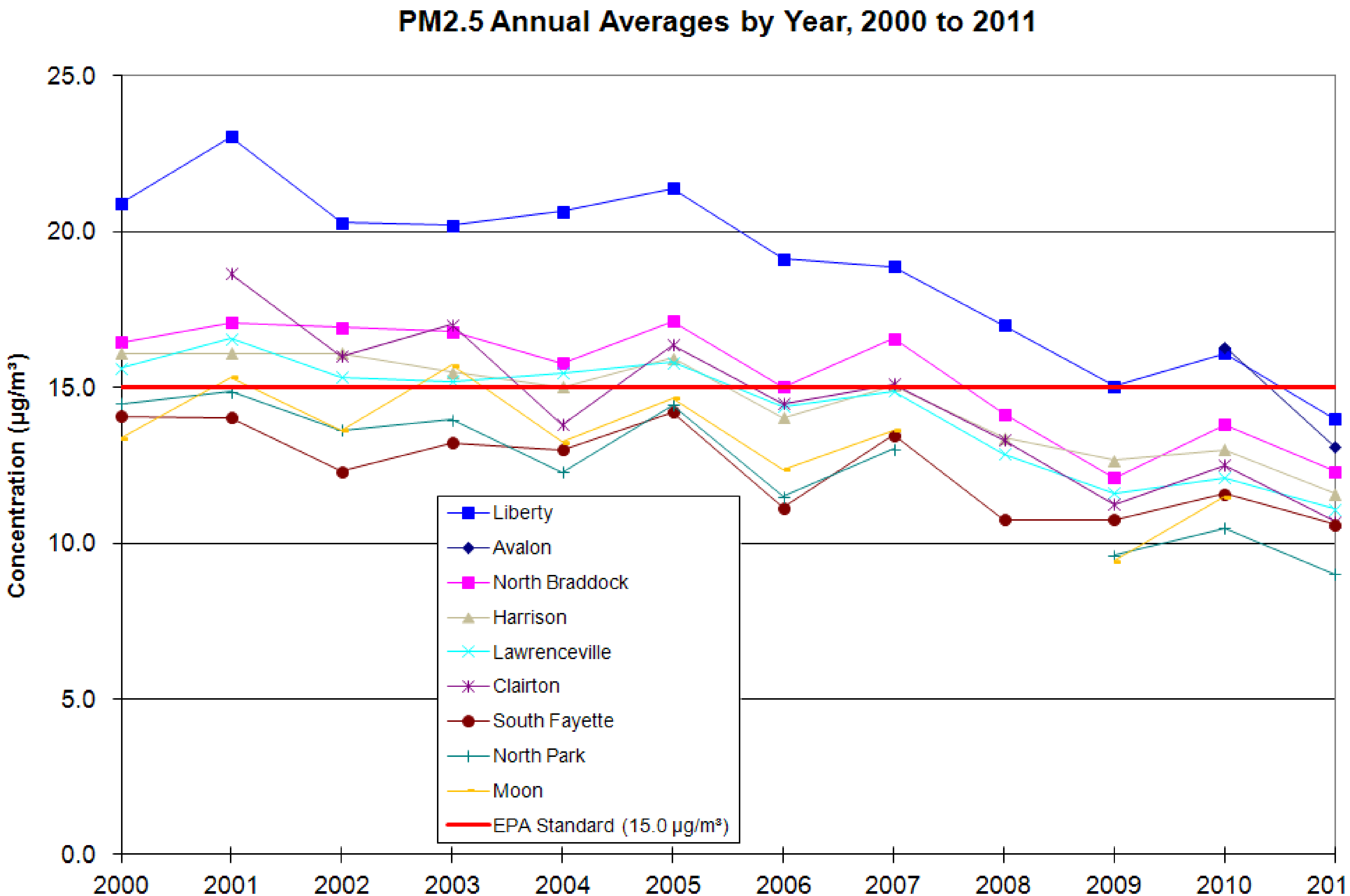
Particulate Matter (PM)

- Several studies have documented increased respiratory symptoms or increased hospitalizations for acute respiratory illness in people in association with PM exposures.
- Decreased peak flow has been observed in panels of normal and asthmatic children in association with PM_{10}.

The potential impact of traffic pollution

- Several studies have shown increased respiratory symptoms in children living near roadways with increased traffic density.
- Several studies have shown increased asthma prevalence in relation to traffic exposure (with NO_2 often showing the best single pollutant correlations).

Downtown Pittsburgh, as seen from the Liberty Tunnels (from the south)


PM2.5 Annual Averages by Year, 2000 to 2011
Concentration (µg/m³)
25.0
20.0
15.0
10.0
5.0
0.0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Liberty
Avalon
North Braddock
Harrison
Lawrenceville
Clairton
South Fayette
North Park
Moon
EPA Standard (15.0 µg/m³)

Stebbings 1978

- Pulmonary Function Tests on 224 school children during and after the **Pittsburgh** air pollution episode of 11/75
- 4 exposed and 2 control schools
- Noted strong upward trends in Forced Vital Capacity after episode

Delfino, 1994

- Hospital admissions for respiratory illnesses in Montreal between 1984-88 were 21.8% (9.7-33.8%) higher for 8-hour maximum increase of 38 ppb ozone in the summer
  - Among those >64 years of age
- Asthma admissions in May-October increased by 2.7% over mean levels for each 12 ug/m^3 increase in PM10 levels 3 days prior to admission
- In July and August, admissions were 9.6% higher when SO_4 had exceeded 8.1 ug/m^3 4 days prior to admission day.
- **PM_{10} had not exceeded the NAAQS of 150 ug/m^3 during the time period.**

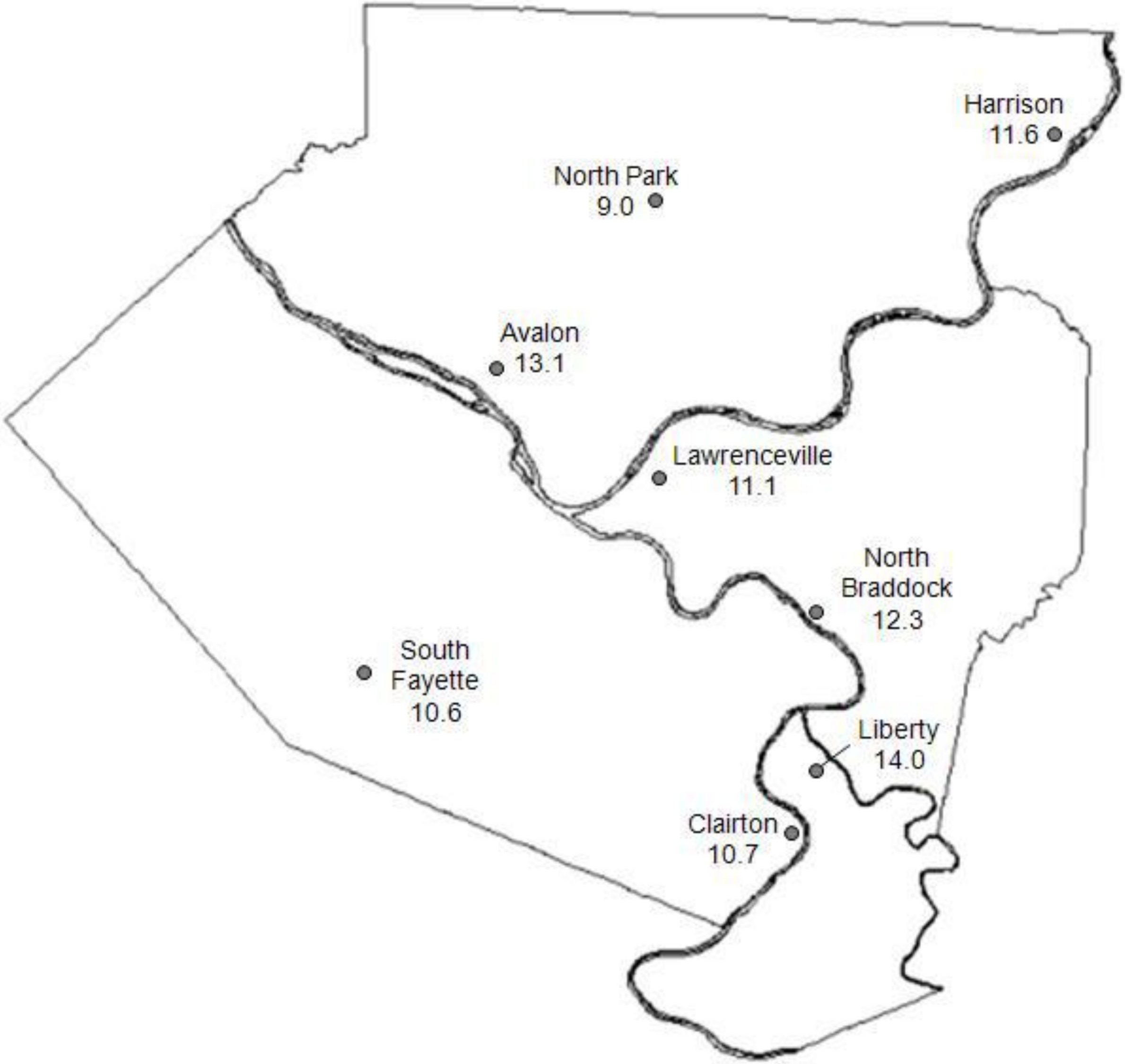
Villeneuve – 2007

- Case-crossover study of asthma ED visits and found that in the summer, SO2, NO2, CO, PM2.5, PM10 and ozone had significant effects .
  – Children aged 2-4 and elderly were most affected
- CO OR=1.48
- NO_2 OR=1.5

Yap CA 2013

- Hospital admission in CA by zip code between 2000-2005
- Daily counts of respiratory admissions for
  - High and low SES by county
- Time series adjusting for time trends, seasonality, day of week, temperature, with pollution lags 0-6 days found an association of asthma and pollution
- For LA, Riverside, San Bernardino, and San Diego Counties, RR 1.03-1.07/10 ug PM2.5

2011 $PM_{2.5}$ FRM Annual Averages by Site, in µg/m³



2011 Exceedances of the Short-Term Federal Standards

Pollutant	Site	Date	Concentration	Standard
Ozone	Lawrenceville	6/6/2011	0.079 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	6/6/2011	0.078 ppm (8-hr.)	0.075 ppm
Ozone	South Fayette	6/6/2011	0.078 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	6/8/2011	0.084 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	6/9/2011	0.080 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	6/18/2011	0.078 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	6/30/2011	0.076 ppm (8-hr.)	0.075 ppm
Ozone	South Fayette	7/1/2011	0.082 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	7/6/2011	0.082 ppm (8-hr.)	0.075 ppm
Ozone	South Fayette	7/7/2011	0.084 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	7/22/2011	0.080 ppm (8-hr.)	0.075 ppm
Ozone	South Fayette	7/22/2011	0.077 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	8/18/2011	0.076 ppm (8-hr.)	0.075 ppm
Ozone	Lawrenceville	9/2/2011	0.095 ppm (8-hr.)	0.075 ppm
Ozone	South Fayette	9/2/2011	0.086 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	9/2/2011	0.078 ppm (8-hr.)	0.075 ppm
Ozone	Harrison	9/3/2011	0.085 ppm (8-hr.)	0.075 ppm
Ozone	Lawrenceville	9/3/2011	0.077 ppm (8-hr.)	0.075 ppm
Ozone	South Fayette	9/3/2011	0.077 ppm (8-hr.)	0.075 ppm
$PM_{2.5}$	Liberty	10 Days	Max = 59.0 μg/m³	35 μg/m³
$PM_{2.5}$	Avalon	1 Day	Max = 35.6 μg/m³	35 μg/m³
$PM_{2.5}$	North Braddock	1 Day	Max = 35.5 μg/m³	35 μg/m³
SO_2	Liberty	53 Days	Max = 450 ppb	75 ppb

July 27, 2011

The Relationship of Ambient Ozone and PM2.5 Levels and Asthma Emergency Department Visits: Possible Influence of Gender and Ethnicity

Glad, Brink, Talbott, Lee, Xu, Saul, Rager

- Data from UPMC, which serves 60% of Allegheny County
  - 6979 patients seen in 6 EDs between January 2002 and December 2005
  - Discharged with asthma (ICD-9, 493.x)

Daily Air Pollution Data for AC

- Ozone and PM2.5 were obtained from the ACHD Air Quality Program
  - 3 ozone monitors
  - 2 continuously operating PM2.5 monitors
    - Used ones in center of city, near hospitals of interest
  - Daily 1-hour maximum ozone
  - Daily mean PM2.5
  - Daily mean temperature and humidity

Study Population

- 60.3% Caucasian
  - Mean age 42.4
  - 17.7% over age 65
  - 10.9% under age 14
- 37.8% African Americans
  - Mean age 35.2
  - 7.6% over age 65
  - 18.9% under age 14

Visits for Asthma

- Ranged from 1-19 visits per person
- African Americans had slightly more visits within the time period

The Case-Crossover Design

- First proposed by Maclure in 1991
- Originally designed to avoid selection bias from a case-control study
- Designed to answer the question "Is a particular health event triggered by something that happened just before the health event"
- Basic idea: compare a patient's exposure experience on the day of their outcome (heart attack) with their exposure experience on the day before

Features of Case-Crossover Design

- **Only cases** are analyzed
- The same individuals "cross over" between being cases and being controls
  - The idea is that people cross over between short periods of exposure to hypothetical triggers and much longer periods of unexposed time.

Selecting the Referent (Control) Times

- Referent times act as the individually-matched "controls"
- Approaches to selecting a referent period
  - Basic approach - Match one hazard period to one referent period (matched pair interval approach)
  - Multiple interval approach – Match one hazard period to multiple referent periods
    - Symmetric bi-directional approach
    - Time-stratified approach

Time Stratified Sampling Approach

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

Confounding

- The case-crossover design controls for measured and unmeasured confounders that do not change over time, such as age, gender, genes.
- Confounding by time-varying factors is possible – e.g., seasonal patterns, day of week, long term trends
  - Can be limited by choice of referent time periods

Table 3.—Odds Ratios and Confidence Limits of Single-Lag Models[a] for Ozone, $PM_{2.5}$, and Asthma ED Visits by Race: All Age Groups[b]

	Total population ($N = 10{,}183$)		Caucasian American ($N = 5{,}583$)		African American ($N = 4{,}414$)	
Lag days	OR	95% CI	OR	95% CI	OR	95% CI
1-Hour max ozone						
1. Day 0	1.001	0.982–1.021	0.982	0.957–1.008	1.021	0.992–1.051
2. Day 1	1.016	0.998–1.036	1.012	0.985–1.039	1.011	0.981–1.043
3. Day 2	1.025	1.006–1.044	1.015	0.989–1.041	1.026	0.998–1.055
4. Day 3	1.008	0.990–1.026	0.989	0.965–1.014	1.025	0.997–1.053
5. Day 4	0.998	0.981–1.017	0.999	0.975–1.025	1.001	0.974–1.029
6. Day 5	0.996	0.978–1.013	1.006	0.981–1.031	0.982	0.956–1.009
7. 6-Day average	1.022	0.990–1.055	1.001	0.958–1.046	1.034	0.985–1.086
$PM_{2.5}$						
1. Day 0	1.005	0.970–1.040	0.999	0.970–1.040	0.983	0.933–1.036
2. Day 1	1.036	1.001–1.073	1.026	0.977–1.077	1.055	1.001–1.112
3. Day 2	1.032	0.999–1.068	0.997	0.952–1.044	1.067	1.015–1.122
4. Day 3	1.017	0.984–1.051	0.972	0.929–1.017	1.053	1.002–1.106
5. Day 4	1.006	0.974–1.038	0.972	0.930–1.017	1.038	0.989–1.090
6. Day 5	0.994	0.963–1.027	0.977	0.934–1.022	1.002	0.954–1.053
7. 6-Day average	1.040	0.984–1.100	0.975	0.904–1.053	1.088	1.001–1.184

[a]All models are adjusted for day 0 temperature.
[b]All results are for 10-unit increase in ozone and $PM_{2.5}$.

Glad, Brink, Talbott 2012

Conclusions

- A 10 ppb increase in the 1-hour daily maximum ozone level was significantly related to a 2.5% increase in asthma ED visits 2 days later
- When considering $PM_{2.5}$ also, ozone contributed a 2.1% increase 2 days later.
- One day after PM2.5 exposure, a 3.6 % increase in asthma ED visits occurred

Conclusions continued

- Although the entire population were affected 2 days after a $PM_{2.5}$ pollution event, this effect was not significant among Caucasians (1.015, 0.989-1.041)
  - It was higher among African Americans, 1.025, 0.997-1.053, driving the overall effect

Possible reasons for differences

- Access to medical care
- Access to air conditioning
- Intrinsic differences
- Different distributions of pollutants

Strengths and Limitations

- ED visits provide a strong and specific outcome measure
- Use of case-crossover design allows control for seasonality, secular trends, and time-invariant factors
- Use of a single monitor to estimate exposure
- Sample of ED visits may not be representative of all ED visits

Current Work:
Asthma Predictive Modeling
Sharma, Brink

Statistical Methodology

- Mixed Model longitudinal analysis using Poisson regression is used analyze daily times series of asthma, circulatory and respiratory counts from 2004-2005
- Risks are estimated and presented in the tables as rate ratio

Results to date

- Based upon asthma hospitalization occurring in 2004-2005, a significant increase in asthma hospitalizations with same-day increase in PM2.5 was noted.

Conclusions

- Recent studies conducted in Pittsburgh indicate an effect of both ozone and $PM_{2.5}$ on asthma exacerbations in Pittsburgh, PA