American Public Health Association

# Methodological Considerations in Assessing Effects of Air Pollution on Human Health

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# General Background

- Air pollution is typically measured as one or more specific chemically-defined particle, such as ozone or carbon monoxide, or a composite measure of particle mass (PM)

- Epidemiological studies examine associations between AQI and health endpoint(s) such as hospital admission, death, doctor visit, or pulmonary function

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# Types of Epidemiological Studies

- Acute Studies that relate health effects in large populations to pollutant levels (or changes in pollutant levels) during a period up to the health event
- Prospective cohort studies that relate air monitoring to health outcomes in a large number of individuals followed for many years
- Cross-sectional studies that compare measured pollutants to the health status of different populations with different long-term exposures.

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# Development of Modeling Approaches

- Important history:
  - 1952 London disaster
  - Harvard Six-city study
  - ACS study
- Historical belief in a presumption of a threshold level of exposure needed to cause harm
- Desire to have an overall estimate of the effect of the pollutant on the health endpoint
- Need methods to handle confounding factors such as seasonal conditions and long-term trends
- How to attribute impact of the pollutants in the face of complicated confounding factors

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# Statistical Issues of Air Pollution Models

- Confounding variables to consider
- Lagged timeframe for confounders and pollutant to health end-point
- Measurement errors in pollutant or confounding variables
- One or more pollutant considered jointly
- Method to obtain single estimate of pollutant's effect on the health endpoint(s)
- Correlation in confounders
- Methods to control for long-term trends and weather conditions have suggested smoothing procedures
  - Generalized Additive Models (loess smoothing)
  - General Linear Models (cubic spline smoothing)

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# Model Variables to Consider

- Time (long-term trend)
- Day of week
- Weather—temp, relative humidity, dewpoint, wind, barometric pressure, etc.
- Pre-existing health condition(s)
- Distance from pollutant measured (value of measured exposure)
- Others?

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# Model Details
# To Smooth or Not to Smooth, and How Much to Smooth?

- Long-term trend
  - Monthly, quarterly, bi-weekly knots if GLM and pattern/start date of consistent knots
  - % for loess if GAM
- Weather
  - Number and location of knots if GLM
  - % for loess if GAM
- Day of week– six indicator variables
- Pollutant—not smoothed, one coefficient

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# Example Model

- AQI:  PM2.5 (from among approximately 50 different measured chemicals)
- GLM, Poisson regression framework due to count response data
- Predictor variables include time, temperature, relative humidity, day of week and individual AQI
- Mortality measures are daily counts of causes of death and age of the decedent (all deaths, cardiovascular, cancer, respiratory or other non-accidental deaths and either all ages, those at least 65 years of age, or less than 65 years of age)

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# Phoenix
# Differences in Estimated Effect of PM2.5 by Distance from PM2.5 Measurement
# All Cardiovascular Causes of Death

| | 5 Mile | | 15 Mile | | County Radius | |
|---|---|---|---|---|---|---|
| AQI | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value |
| PM2.5 LAG0 | -0.0110 | -2.54 | -0.0047 | -2.12 | -0.0020 | -1.13 |
| PM2.5 LAG1 | 0.0109 | 2.26 | 0.0068 | 2.78 | 0.0042 | 2.07 |
| PM2.5 LAG2 | 0.0020 | 0.42 | -0.0001 | -0.05 | 0.0001 | 0.06 |
| PM2.5 LAG3 | 0.0024 | 0.52 | 0.0016 | 0.70 | 0.0005 | 0.26 |
| PM2.5 LAG4 | 0.0011 | 0.23 | 0.0022 | 0.94 | -0.0005 | -0.25 |
| PM2.5 LAG5 | 0.0002 | 0.05 | -0.0001 | -0.05 | 0.0004 | 0.21 |


Lag 0 indicates pollution measured on the same day as the day of death.

# Phoenix
# Differences in Estimated Effect of PM2.5 by Model Variables
# 65+ Cardiovascular Causes of Death

| Mortality Category | Model variables | AQI | Coefficient | t-value | Null deviance | Null dev df | Residual dev | Residual dev df |
|---|---|---|---|---|---|---|---|---|
| Cardio 65+ County | AQI, time, Temp, rh, dayweek | PM2.5 LAG0 | 0.0001 | 0.07 | 1168.40 | 911 | 904.60 | 887 |
| Cardio 65+ County | AQI, time, Temp, rh, dayweek | PM2.5 LAG1 | 0.0027 | 1.96 | 1156.99 | 911 | 904.63 | 887 |
| Cardio 65+ County | AQI | PM2.5 LAG0 | 0.0042 | 3.38 | 1266.13 | 975 | 1251.50 | 974 |
| Cardio 65+ County | AQI | PM2.5 LAG1 | 0.0057 | 4.66 | 1239.89 | 974 | 1212.97 | 973 |
| Cardio 65+ County | AQI, time | PM2.5 LAG0 | 0.0005 | 0.38 | 1266.13 | 975 | 1029.07 | 963 |
| Cardio 65+ County | AQI, time | PM2.5 LAG1 | 0.0028 | 2.17 | 1239.89 | 974 | 1014.72 | 962 |
| Cardio 65+ County | AQI, weather | PM2.5 LAG0 | 0.0006 | 0.51 | 1168.40 | 911 | 979.33 | 904 |
| Cardio 65+ County | AQI, weather | PM2.5 LAG1 | 0.0028 | 2.30 | 1156.99 | 911 | 975.93 | 904 |
| Cardio 65+ County | AQI, dayweek | PM2.5 LAG0 | 0.0039 | 3.17 | 1266.13 | 975 | 1234.05 | 968 |
| Cardio 65+ County | AQI, dayweek | PM2.5 LAG1 | 0.0054 | 4.47 | 1239.89 | 974 | 1197.47 | 967 |

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# Atlanta
# Differences in Estimated Effect of PM2.5 by Model Variables
## 65+ Cardiovascular Causes of Death

| Mortality Category | Model Variables | AQI | Coefficient | t-value | Null deviance | Null dev df | Residual deviance | Residual dev df |
|---|---|---|---|---|---|---|---|---|
| Cardio 65+ County | AQI, time, Temp, dewpoint, dayweek | PM2.5 LAG0 | 0.0017 | 0.77 | 772.68 | 636 | 687.83 | 612 |
| Cardio 65+ County | AQI, time, Temp, dewpoint, dayweek | PM2.5 LAG1 | -0.0001 | -0.05 | 776.06 | 636 | 685.91 | 612 |
| Cardio 65+ County | AQI | PM2.5 LAG0 | -0.0020 | -1.03 | 773.73 | 637 | 772.46 | 636 |
| Cardio 65+ County | AQI | PM2.5 LAG1 | -0.0031 | -1.56 | 776.06 | 636 | 773.08 | 635 |
| Cardio 65+ County | AQI, time | PM2.5 LAG0 | 0.0016 | 0.78 | 773.73 | 637 | 698.26 | 625 |
| Cardio 65+ County | AQI, time | PM2.5 LAG1 | 0.0003 | 0.14 | 776.06 | 636 | 698.52 | 624 |
| Cardio 65+ County | AQI, weather | PM2.5 LAG0 | 0.0017 | 0.82 | 772.68 | 636 | 719.78 | 629 |
| Cardio 65+ County | AQI, weather | PM2.5 LAG1 | 0.0019 | 0.89 | 776.06 | 636 | 719.32 | 629 |
| Cardio 65+ County | AQI, dayweek | PM2.5 LAG0 | -0.0019 | -0.96 | 773.73 | 637 | 769.22 | 630 |
| Cardio 65+ County | AQI, dayweek | PM2.5 LAG1 | -0.0029 | -1.49 | 776.06 | 636 | 767.32 | 629 |

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# Phoenix
# Differences in Estimated Effect of PM2.5 by Changes in Smoothing Knots
# 65+ Cardiovascular Causes of Death

| Mortality Category | Temp/RH Knots | Time Knots | AQI | Coefficient | t-value | Null deviance | Null dev df | Residual deviance | Residual dev df |
|---|---|---|---|---|---|---|---|---|---|
| Cardio 65+ County | 2 | 10 | PM2.5 LAG0 | 0.0001 | 0.07 | 1168.40 | 911 | 904.60 | 887 |
| Cardio 65+ County | 2 | 10 | PM2.5 LAG1 | 0.0027 | 1.96 | 1156.99 | 911 | 904.63 | 887 |
| Cardio 65+ County | 2 | Monthly | PM2.5 LAG0 | -0.0012 | -0.79 | 1168.40 | 911 | 861.28 | 861 |
| Cardio 65+ County | 2 | Monthly | PM2.5 LAG1 | 0.0019 | 1.22 | 1156.99 | 911 | 863.73 | 861 |
| Cardio 65+ County | 2 | Quarterly Starting 03/20/1995 | PM2.5 LAG0 | -0.0002 | -0.13 | 1168.40 | 911 | 906.66 | 885 |
| Cardio 65+ County | 2 | Quarterly Starting 03/20/1995 | PM2.5 LAG1 | 0.0029 | 1.95 | 1156.99 | 911 | 906.87 | 885 |
| Cardio 65+ County | 2 | Quarterly Starting 02/01/1995 | PM2.5 LAG0 | 0.0002 | 0.14 | 1168.40 | 911 | 905.85 | 885 |
| Cardio 65+ County | 2 | Quarterly Starting 02/01/1995 | PM2.5 LAG1 | 0.0030 | 2.15 | 1156.99 | 911 | 905.38 | 885 |
| Cardio 65+ County | 4 | 10 | PM2.5 LAG0 | 0.0002 | 0.13 | 1168.40 | 911 | 895.06 | 883 |
| Cardio 65+ County | 4 | 10 | PM2.5 LAG1 | 0.0028 | 1.99 | 1156.99 | 911 | 898.52 | 883 |

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# Atlanta
# Differences in Estimated Effect of PM2.5 By Changes in Smoothing Knots 65+ Cardiovascular Causes of Death

| Mortality category | Temp/RH Knots | Time Knots | AQI | Coefficient | t-value | Null deviance | Null dev df | Residual deviance | Residual dev df |
|---|---|---|---|---|---|---|---|---|---|
| Cardio 65+ County | 2 | 10 | PM2.5 LAG0 | 0.0017 | 0.77 | 772.68 | 636 | 687.83 | 612 |
| Cardio 65+ County | 2 | 10 | PM2.5 LAG1 | -0.0001 | -0.05 | 776.06 | 636 | 685.91 | 612 |
| Cardio 65+ County | 2 | Monthly | PM2.5 LAG0 | 0.0027 | 1.11 | 772.68 | 636 | 664.36 | 598 |
| Cardio 65+ County | 2 | Monthly | PM2.5 LAG1 | 0.0008 | 0.31 | 776.06 | 636 | 664.44 | 598 |
| Cardio 65+ County | 2 | Quarterly Starting 09/22/1998 | PM2.5 LAG0 | 0.0015 | 0.70 | 772.68 | 636 | 688.33 | 614 |
| Cardio 65+ County | 2 | Quarterly Starting 09/22/1998 | PM2.5 LAG1 | -0.0002 | -0.07 | 776.06 | 636 | 686.46 | 614 |
| Cardio 65+ County | 2 | Quarterly Starting 08/15/1998 | PM2.5 LAG0 | 0.0014 | 0.64 | 772.68 | 636 | 691.46 | 614 |
| Cardio 65+ County | 2 | Quarterly Starting 08/15/1998 | PM2.5 LAG1 | -0.0001 | -0.06 | 776.06 | 636 | 689.33 | 614 |
| Cardio 65+ County | 4 | 10 | PM2.5 LAG0 | 0.0016 | 0.74 | 772.68 | 636 | 681.30 | 608 |
| Cardio 65+ County | 4 | 10 | PM2.5 LAG1 | -0.0003 | -0.12 | 776.06 | 636 | 680.27 | 608 |

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# Phoenix
# Differences in Estimated Effect of PM2.5 With Additional Weather Knots Three Categories of Causes of Death

| Mortality Category | Temp/Rel humidity Knots | Time Knots | AQI | Coefficient | t-value |
|---|---|---|---|---|---|
| Cancer 65+ County | 2 | 10 | PM2.5 LAG0 | -0.0010 | -0.52 |
| Cancer 65+ County | 4 | 10 | PM2.5 LAG0 | -0.0010 | -0.49 |
| Cancer 65+ County | 2 | 10 | PM2.5 LAG1 | -0.0024 | -1.19 |
| Cancer 65+ County | 4 | 10 | PM2.5 LAG1 | -0.0021 | -1.06 |
| Resp 65+ County | 2 | 10 | PM2.5 LAG0 | -0.0024 | -0.93 |
| Resp 65+ County | 4 | 10 | PM2.5 LAG0 | -0.0024 | -0.91 |
| Resp 65+ County | 2 | 10 | PM2.5 LAG1 | -0.0031 | -1.20 |
| Resp 65+ County | 4 | 10 | PM2.5 LAG1 | -0.0031 | -1.21 |
| Cardio 65+ County | 2 | 10 | PM2.5 LAG0 | 0.0001 | 0.07 |
| Cardio 65+ County | 4 | 10 | PM2.5 LAG0 | 0.0002 | 0.13 |
| Cardio 65+ County | 2 | 10 | PM2.5 LAG1 | 0.0027 | 1.96 |
| Cardio 65+ County | 4 | 10 | PM2.5 LAG1 | 0.0028 | 1.99 |

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# Atlanta
# Differences in Estimated Effect of PM2.5 With Additional Weather Knots
# Three Categories of Causes of Death

| Mortality Category | Temp/Dew point Knots | Time Knots | AQI | Coefficient | t-value |
|---|---|---|---|---|---|
| Cancer 65+ County | 2 | 10 | PM2.5 LAG0 | 0.0067 | 2.29 |
| Cancer 65+ County | 4 | 10 | PM2.5 LAG0 | 0.0065 | 2.19 |
| Cancer 65+ County | 2 | 10 | PM2.5 LAG1 | 0.0059 | 1.93 |
| Cancer 65+ County | 4 | 10 | PM2.5 LAG1 | 0.0060 | 1.94 |
| Resp 65+ County | 2 | 10 | PM2.5 LAG0 | 0.0052 | 1.40 |
| Resp 65+ County | 4 | 10 | PM2.5 LAG0 | 0.0050 | 1.33 |
| Resp 65+ County | 2 | 10 | PM2.5 LAG1 | 0.0077 | 1.97 |
| Resp 65+ County | 4 | 10 | PM2.5 LAG1 | 0.0073 | 1.86 |
| Cardio 65+ County | 2 | 10 | PM2.5 LAG0 | 0.0017 | 0.77 |
| Cardio 65+ County | 4 | 10 | PM2.5 LAG0 | 0.0016 | 0.74 |
| Cardio 65+ County | 2 | 10 | PM2.5 LAG1 | -0.0001 | -0.05 |
| Cardio 65+ County | 4 | 10 | PM2.5 LAG1 | -0.0003 | -0.12 |

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# Phoenix
# Differences in Estimated Effect of PM2.5 With Addition of Day of the Week Indicators Three Categories of Causes of Death

| Mortality Category | Model Variables | AQI | Coefficient | t-value |
|---|---|---|---|---|
| Cardio 65+ County | AQI | PM2.5 LAG0 | 0.0042 | 3.38 |
| Cardio 65+ County | AQI, dayweek | PM2.5 LAG0 | 0.0039 | 3.17 |
| Cardio 65+ County | AQI | PM2.5 LAG1 | 0.0057 | 4.66 |
| Cardio 65+ County | AQI, dayweek | PM2.5 LAG1 | 0.0054 | 4.47 |
| Cancer 65+ County | AQI | PM2.5 LAG0 | -0.0002 | -0.12 |
| Cancer 65+ County | AQI, dayweek | PM2.5 LAG0 | -0.0004 | -0.25 |
| Cancer 65+ County | AQI | PM2.5 LAG1 | -0.0006 | -0.37 |
| Cancer 65+ County | AQI, dayweek | PM2.5 LAG1 | -0.0007 | -0.46 |
| Resp 65+ County | AQI | PM2.5 LAG0 | 0.0069 | 2.95 |
| Resp 65+ County | AQI, dayweek | PM2.5 LAG0 | 0.0070 | 2.96 |
| Resp 65+ County | AQI | PM2.5 LAG1 | 0.0059 | 2.51 |
| Resp 65+ County | AQI, dayweek | PM2.5 LAG1 | 0.0059 | 2.47 |

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# Atlanta
# Differences in Estimated Effect of PM2.5 With Addition of Day of the Week Indicators Three Categories of Causes of Death

| Mortality Category | Model Variables | AQI | Coefficient | t-value |
|---|---|---|---|---|
| Cancer 65+ County | AQI Only | PM2.5 LAG0 | 0.0047 | 1.91 |
| Cancer 65+ County | AQI, dayweek | PM2.5 LAG0 | 0.0048 | 1.94 |
| Cancer 65+ County | AQI Only | PM2.5 LAG1 | 0.0045 | 1.83 |
| Cancer 65+ County | AQI, dayweek | PM2.5 LAG1 | 0.0041 | 1.66 |
| Resp 65+ County | AQI Only | PM2.5 LAG0 | -0.0032 | -0.94 |
| Resp 65+ County | AQI, dayweek | PM2.5 LAG0 | -0.0035 | -1.03 |
| Resp 65+ County | AQI Only | PM2.5 LAG1 | -0.0007 | -0.21 |
| Resp 65+ County | AQI, dayweek | PM2.5 LAG1 | -0.0011 | -0.31 |
| Cardio 65+ County | AQI Only | PM2.5 LAG0 | -0.0020 | -1.03 |
| Cardio 65+ County | AQI, dayweek | PM2.5 LAG0 | -0.0019 | -0.96 |
| Cardio 65+ County | AQI Only | PM2.5 LAG1 | -0.0031 | -1.56 |
| Cardio 65+ County | AQI, dayweek | PM2.5 LAG1 | -0.0029 | -1.49 |

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# Conclusions

- Distance from the location of the measurement of the PM2.5 influences the estimated effect of PM2.5 pollutant for Phoenix
- Day of the week adds very little to the estimated effect of PM2.5 for both Atlanta and Phoenix
- Additional knots (smoothing) on weather adds very little to the estimated effect of PM2.5 for Atlanta and Phoenix for three categories of decedents

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# Conclusions

- Location of knots seems to have little influence on the estimated effect of PM2.5 on mortality in Phoenix and Atlanta
- Weather or Time seem to influence the estimated effect of PM2.5 most, but in no consistent manner for Atlanta and Phoenix --inclusion of both is nearly the same as one or the other

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# Reference

- "Estimating the Effects of Air Pollution on Human Health: Modeling Issues," Scientific Evidence Review, Current Issues at the Crossroads of Science, Technology and the Law, Monograph No. 7, American Bar Association Section of Science & Technology Law, C. Cwik and H. Witt, Editors, 2006, pages 147-158.

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