Training Course on Seamless Prediction of Air Pollution in Africa

Health Impact Assessments

Aurelio Tobías *(Spanish Research Council)*

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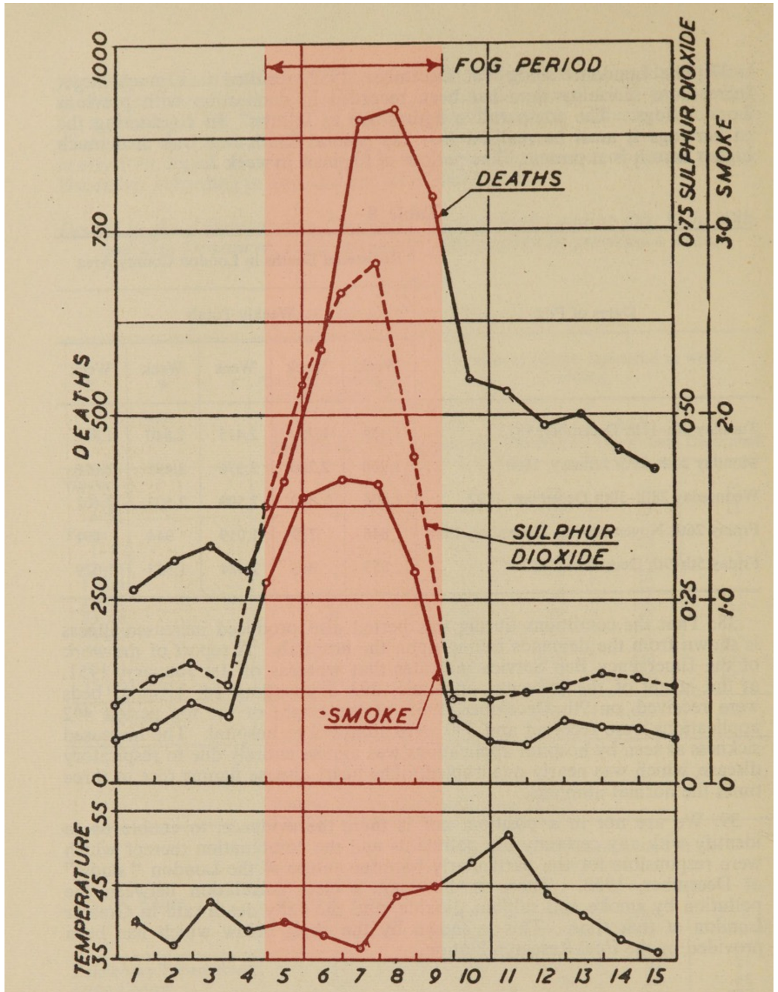
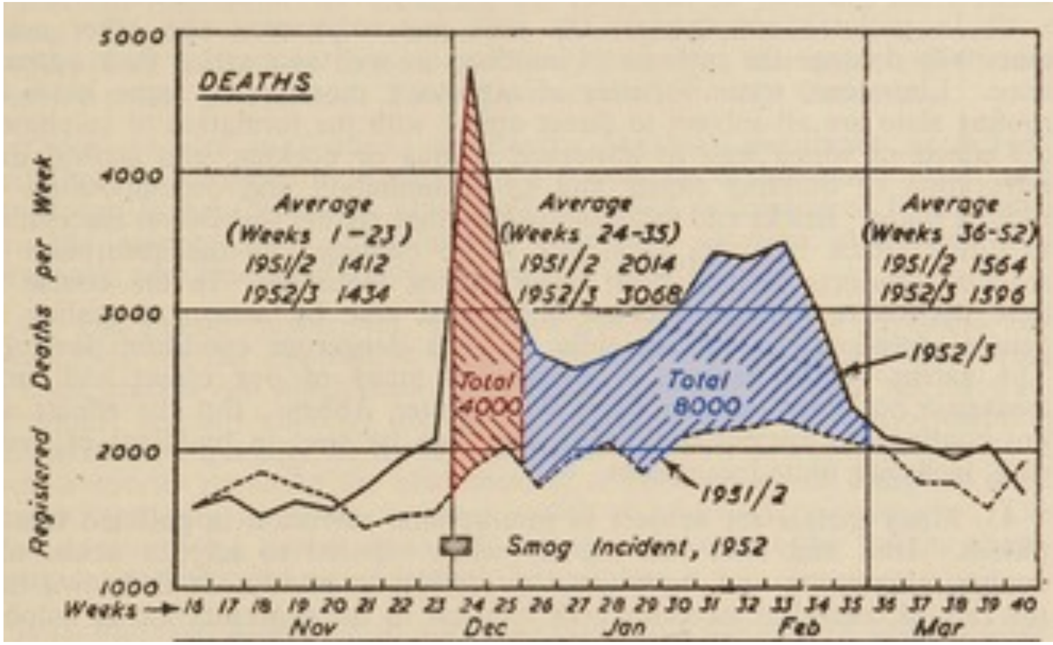
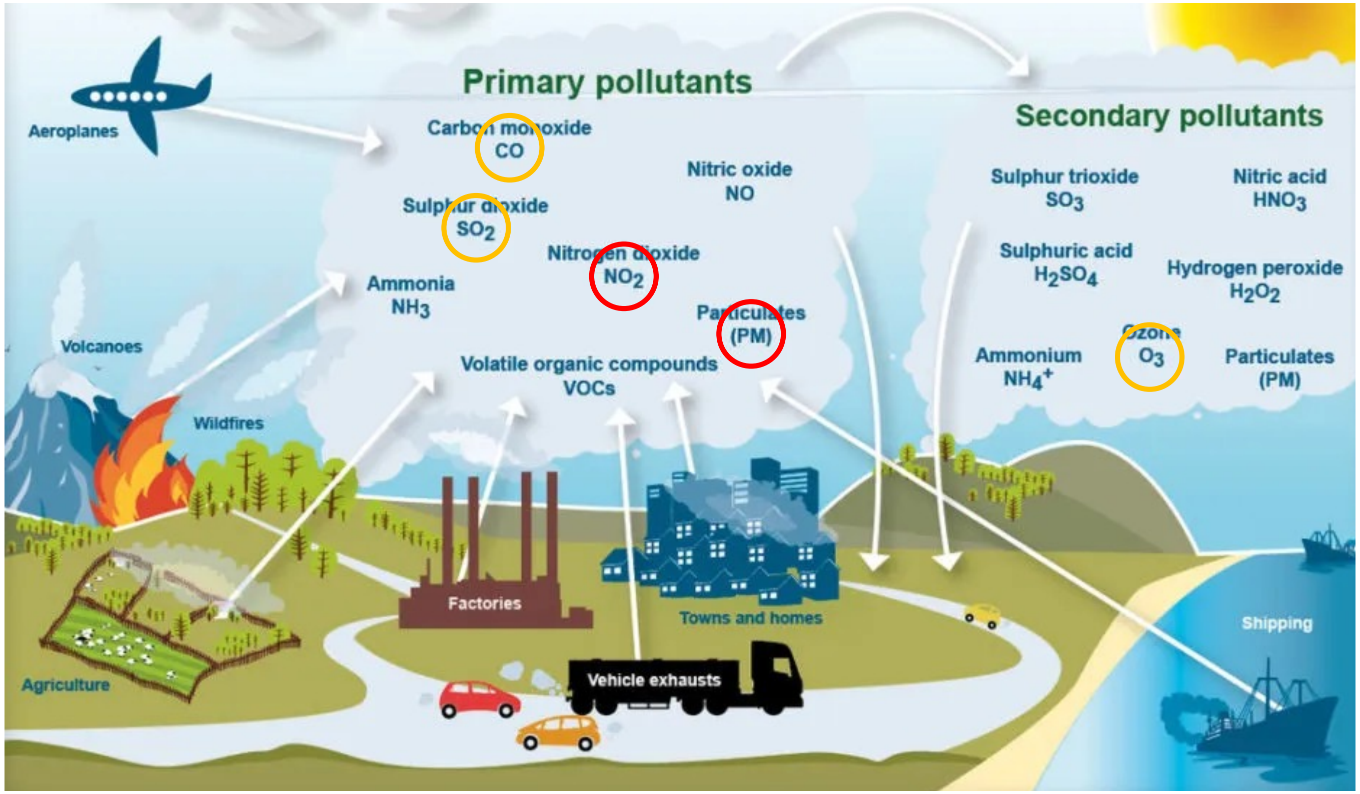
Deadly smog in London, 1952



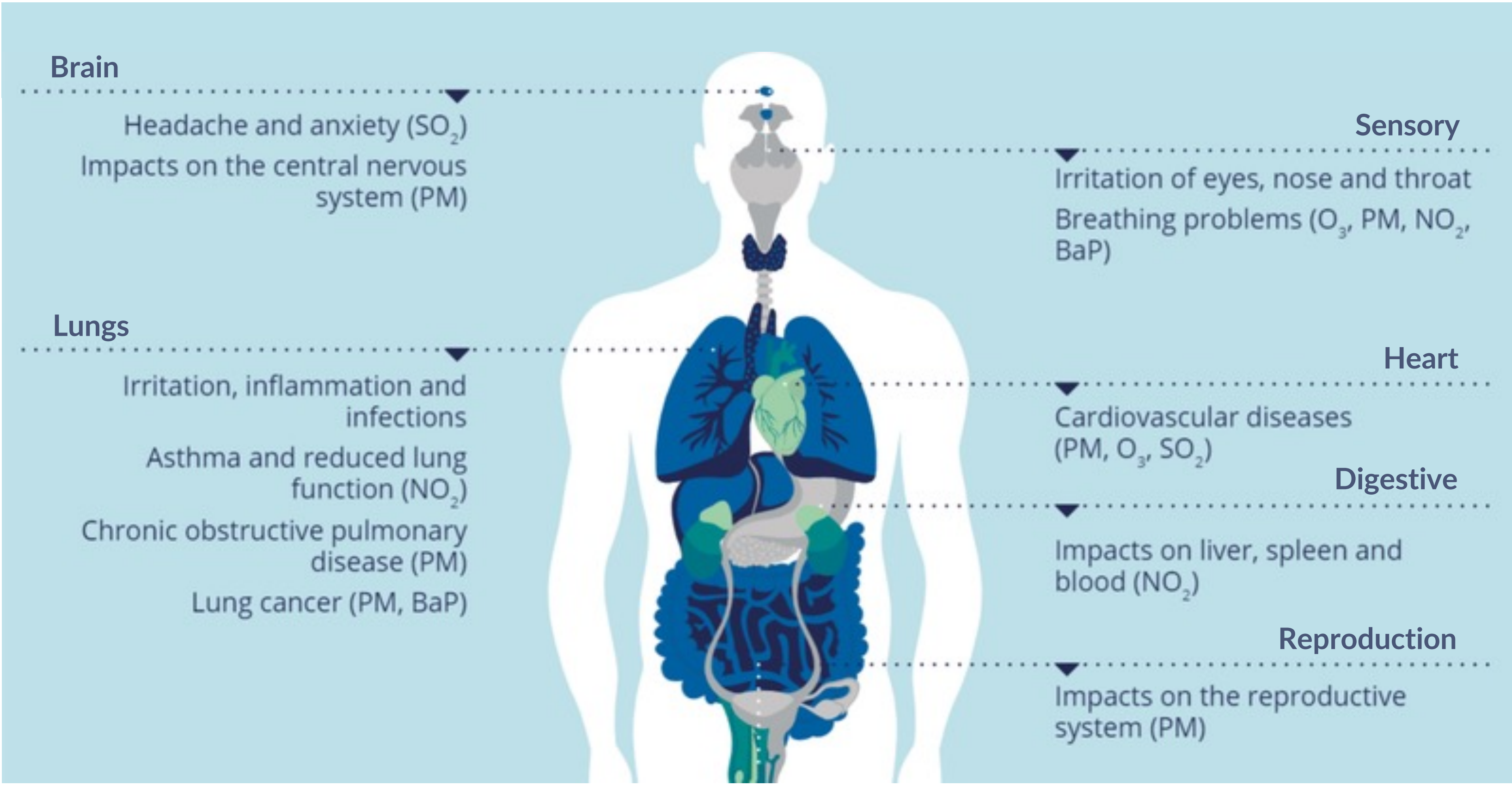
DEATHS, AIR POLLUTION AND TEMPERATURE DURING DECEMBER, 1952, IN GREATER LONDON (Population 8½ millions)



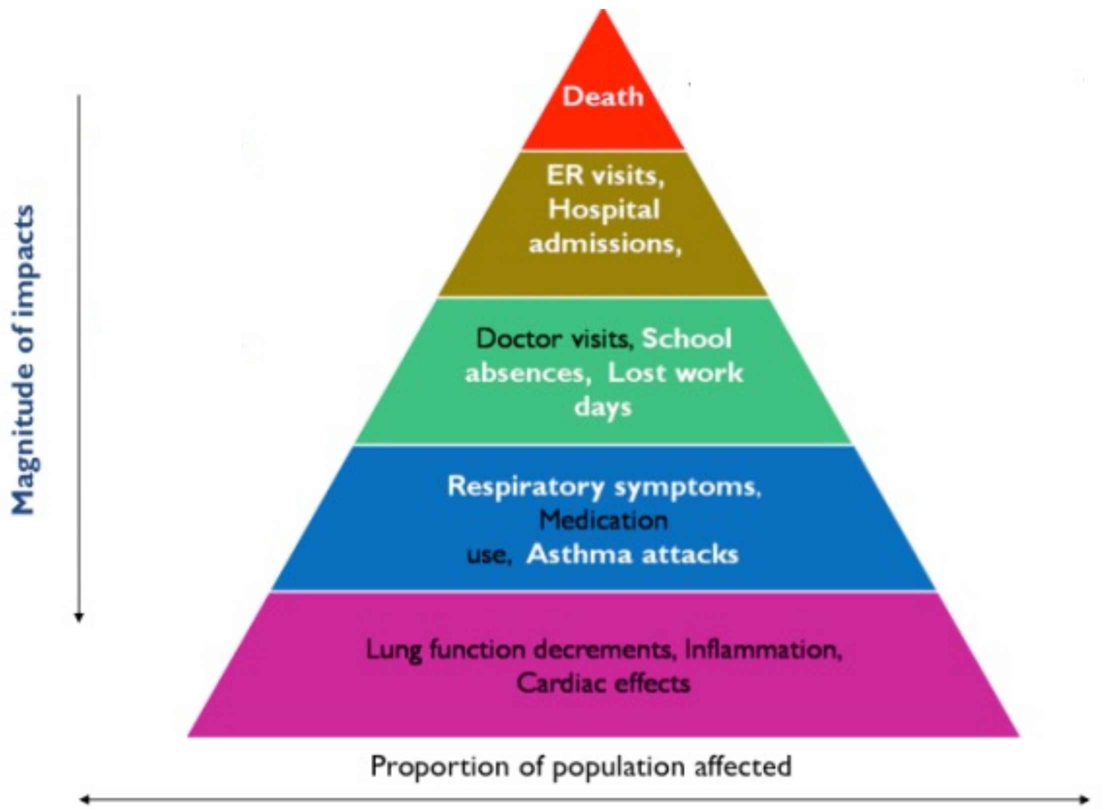
Major air pollutants



Health effects of air pollution



Pyramid of health outcomes

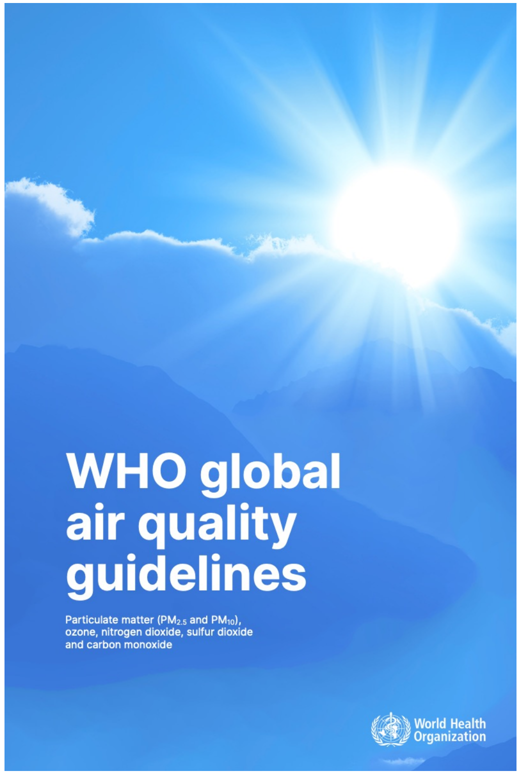


Regulatory Concentrations

Table 0.1. Recommended AQG levels and interim targets

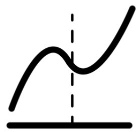
Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, µg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
NO_2, µg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
SO_2, µg/m³	24-hour[a]	125	50	–	–	40
CO, mg/m³	24-hour[a]	7	–	–	–	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

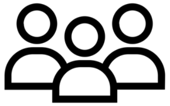


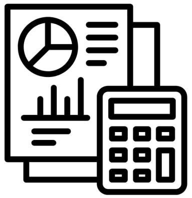
Assessing health effects and impacts

- **Health effects** refers to changes in health status caused by an exposure
  - Short-term effects account for acute impact on health after an immediate exposure (time-series studies)



  - Long-term effects involve chronic health effect after a cumulative exposure (cohort studies)





- **Health impact assessment** evaluates potential health effects of proposed actions relative to an exposure, to provide advice for decision-making process that will protect health

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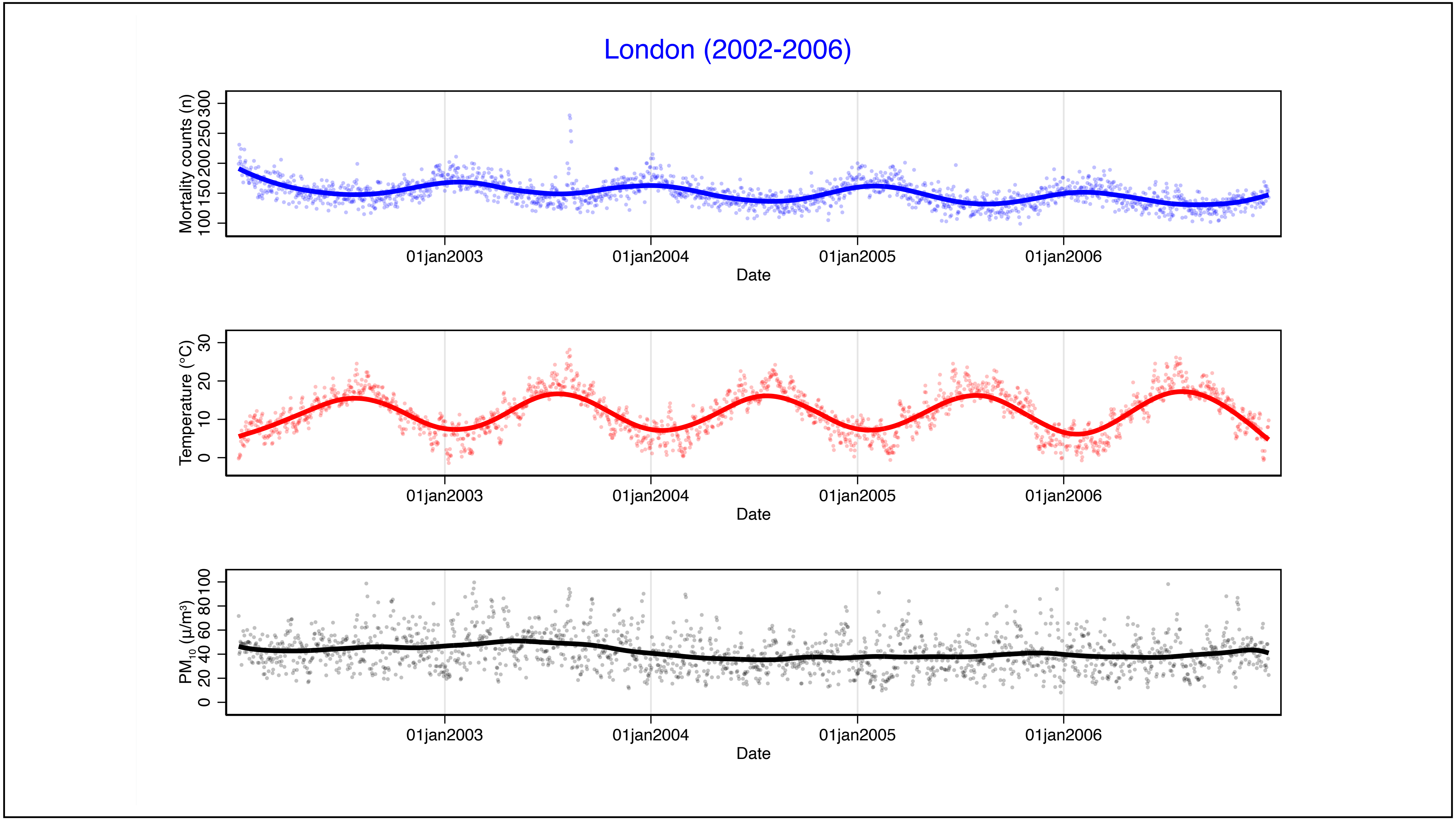
Short-term health effects

Aurelio Tobías *(Spanish Research Council)*

Introduction

- Research question – *"Is there an association between day-to-day variation in the environmental exposure and daily risk of health outcome"?*
- Health outcomes and environmental exposures are characterized by similar time-trends
- Measures of individual predictors are usually not available
- Need of a study design relaying on between-day comparison within the same population and able to control for time-trends to disentangle short-term health effects of air pollution


London (2002-2006)
Mortality counts (n)
100 150 200 250 300
01jan2003
01jan2004
01jan2005
01jan2006
Date
Temperature (°C)
0
10
20
30
01jan2003
01jan2004
01jan2005
01jan2006
Date
PM10 (μ/m³)
0
20
40
60
80
100
01jan2003
01jan2004
01jan2005
01jan2006
Date

Time-series data

- A time-series is a sequence of measurements equally spaced through time
- The unit of analysis is the day, not the individual person
- The health outcome is a count (e.g., number of deaths)

- First week of time-series data in London (Jan 2002 – Dec 2006)

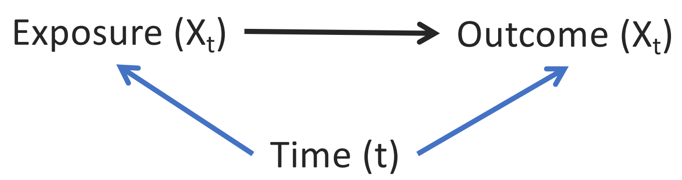
obs	date	deaths	temp	pm10
1.	01jan2002	199	-0.2	71.7
2.	02jan2002	231	0.1	40.2
3.	03jan2002	210	0.9	41.8
4.	04jan2002	203	0.5	50.4
5.	05jan2002	224	4.2	49.4
6.	06jan2002	198	7.1	31.1
7.	07jan2002	180	5.2	48.6

Time-series design

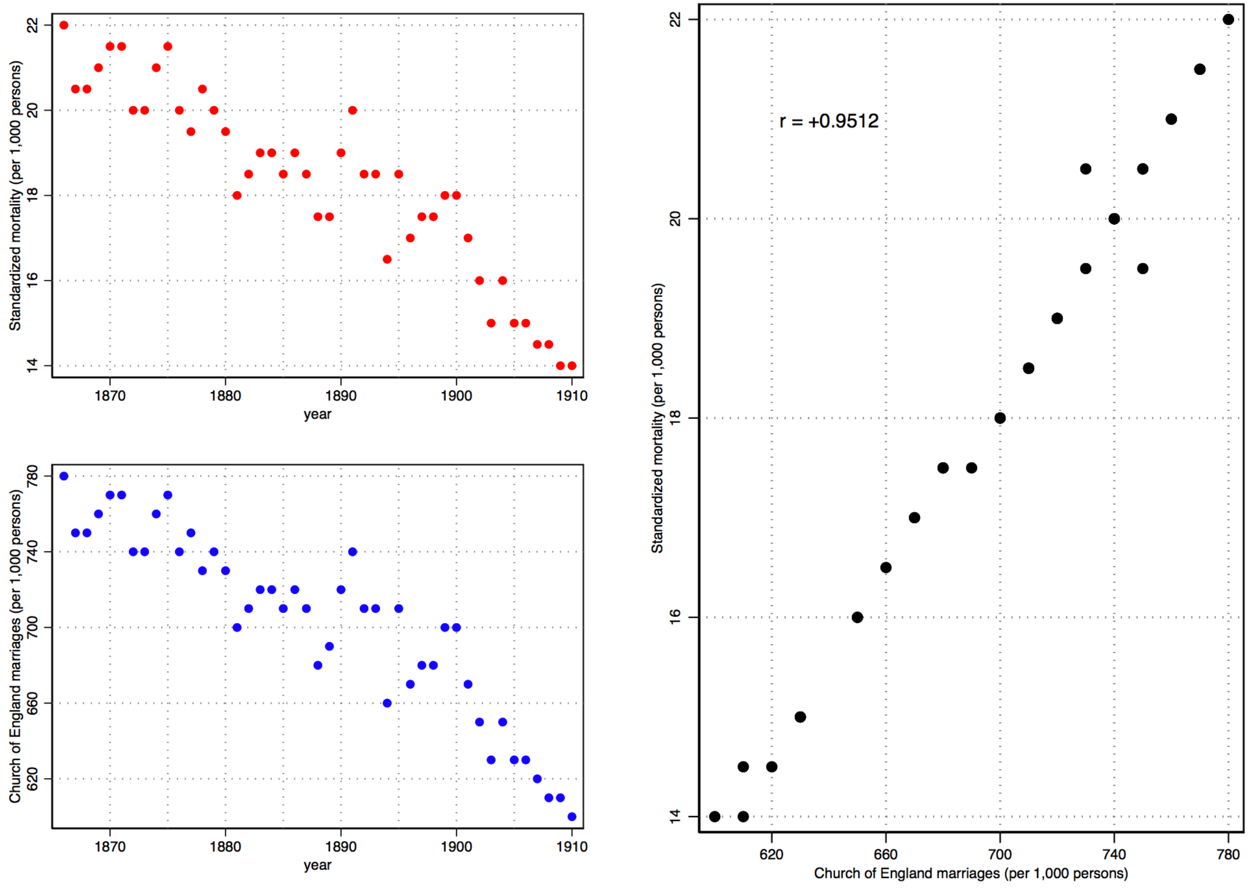
- **Strengths**
  - Use of administratively collected data
  - Same population is compared with itself, focus is day-to-day variation
  - Time-invariant or slowly varying individual risk factors controlled by design (e.g., sex, age, smoking)
- **Limitations**
  - Ecological design based on aggregated, not individual data
  - Not applicable to estimate chronic effects (long-term)
  - Sensitive to choices for statistical modelling

Confounding

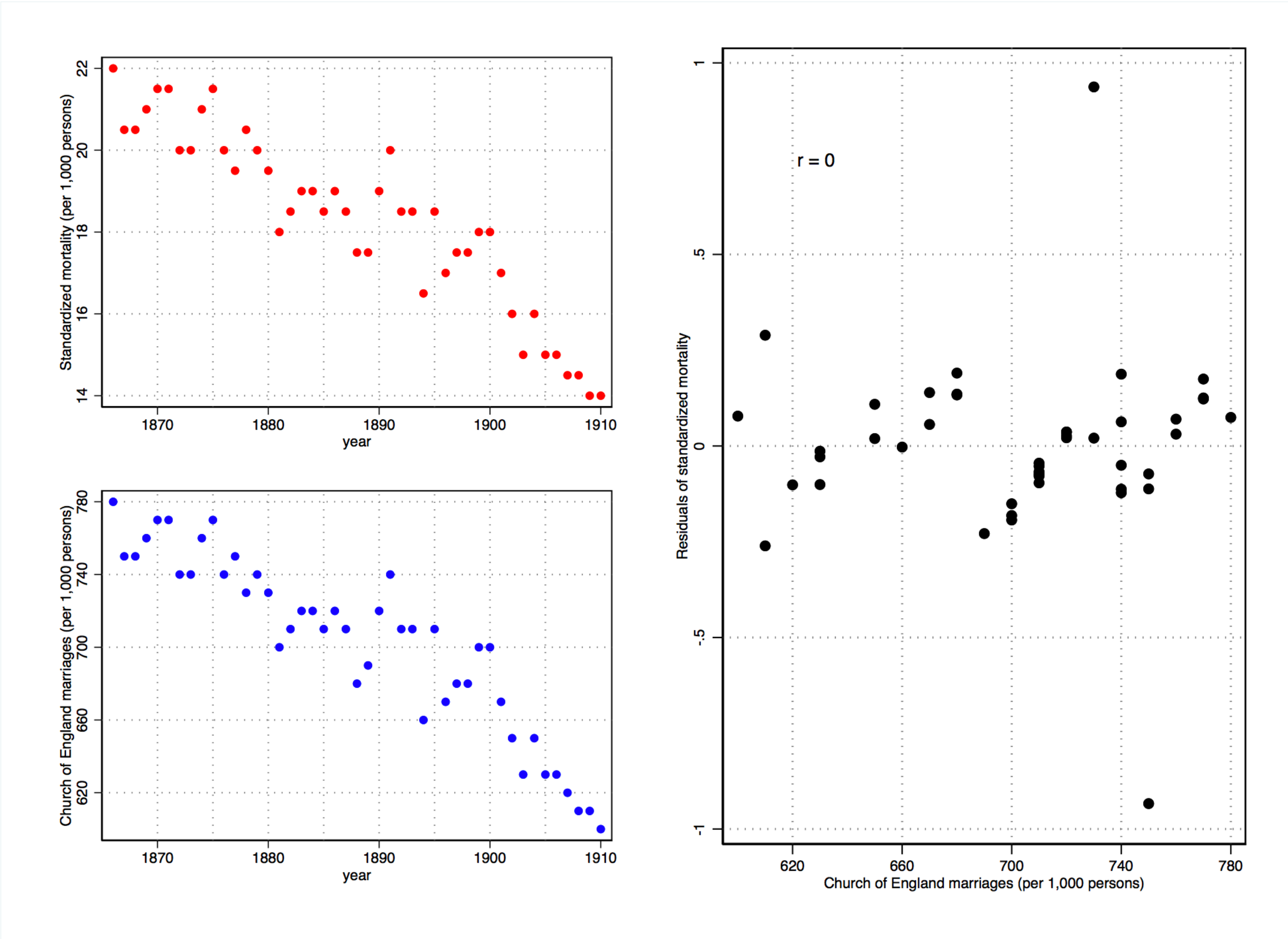
- It must be associated with the exposure (X) being investigated
- It must be independently associated with the outcome (Y) being investigated
- It must not be on the causal pathway between exposure (X) and outcome (Y)



Yule GU. **Why do we sometimes get nonsense correlations between time series?** J Royal Stat Soc Sci. 1926;89:1-64.



Yule GU. **Why do we sometimes get nonsense correlations between time series?** J Royal Stat Soc Sci. 1926;89:1-64.



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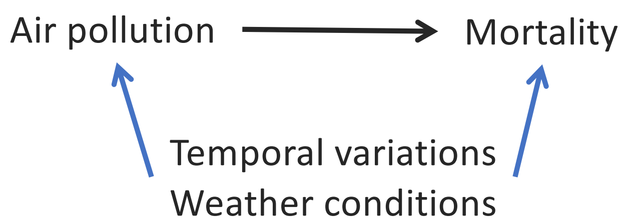


Modelling framework

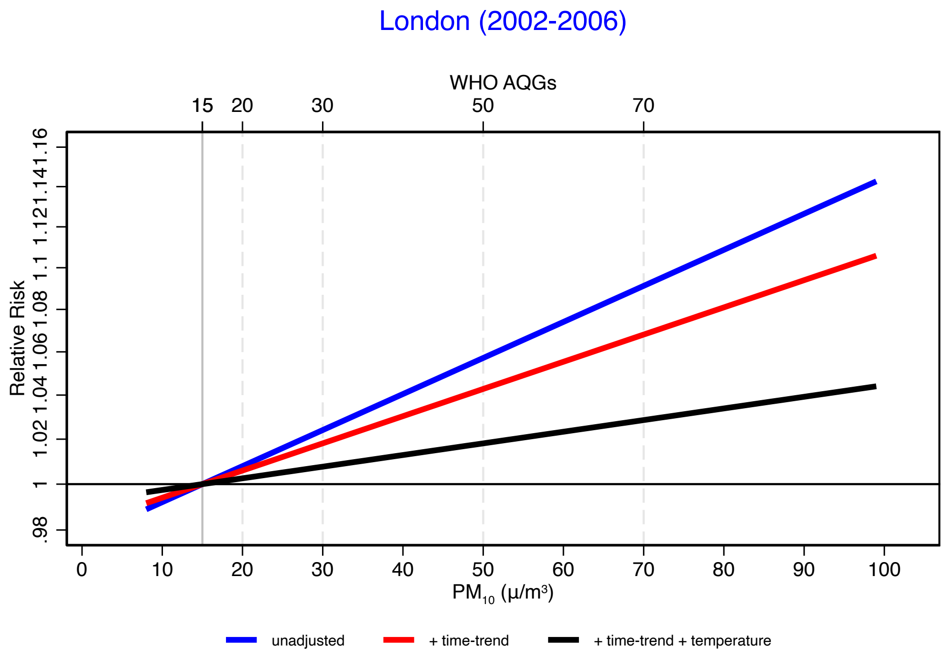
- Similar in principle to any regression analysis but with some specific features
- Poisson regression

$$log(Y_t) = \beta_0 + \beta_1 PM_{10t} + ns(t) + ns(temp)$$

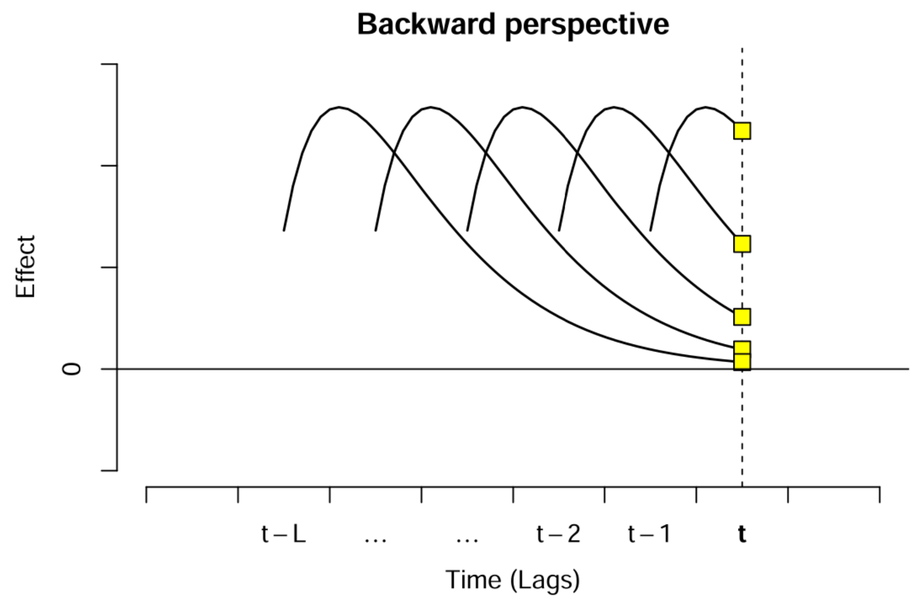
$$Y|x \sim Poisson(\mu)$$

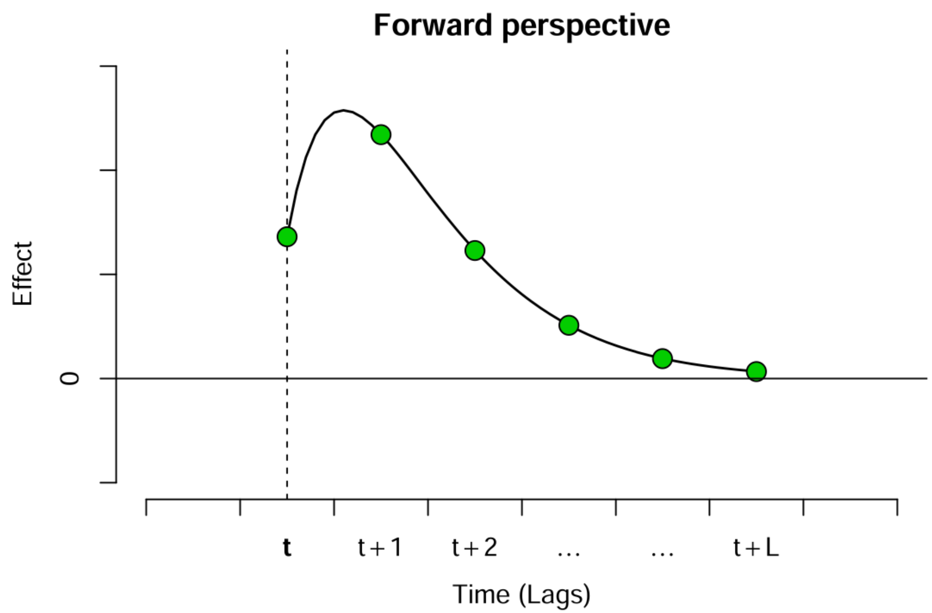
$$with\ E(Y|x) = \mu\ and\ V(Y|x) = \mu$$

  - $exp(\beta_1)$ is the relative risk (RR) for 1 unit increase of the PM_{10} exposure
  - $(RR - 1) \times 100\%$ is the percentage risk increase



Lag effects





- Cumulative effect at time *t* for an exposure in the previous *t-L* days
- Cumulative effect for an exposure at day *t* experienced in the next *t+L* days

Lag variables

- In practice, time-series data is usually analysed with a forward perspective
- It requires generating lagged exposure variables to be fitted in the time-series regression model
- Poisson regression

$$log(Y_t) = \beta_0 + \sum \beta_j \, PM10_{t-j} + ns(t) + ns(temp)$$

$$Y|x \sim Poisson(\mu)$$

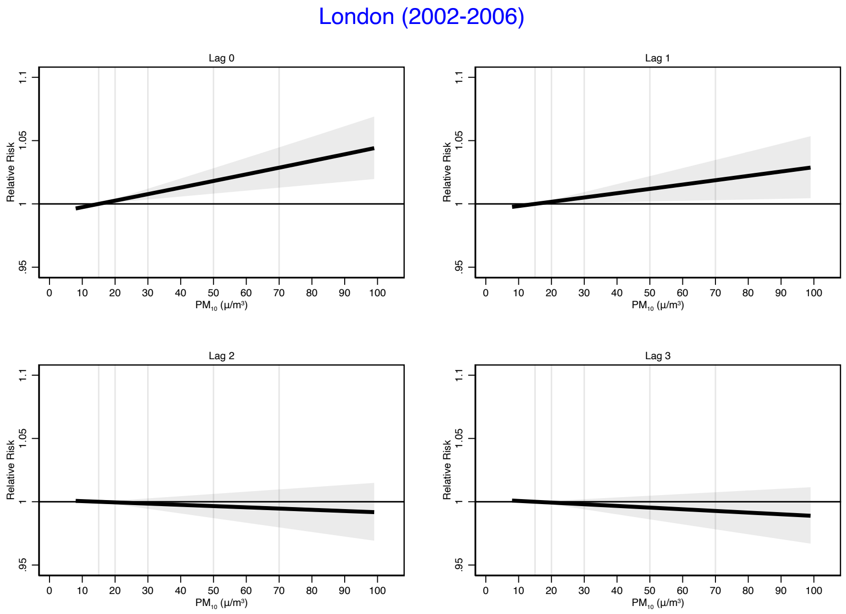
$$with \;\; E(Y|x) = \mu \; and \; V(Y|x) = \mu$$

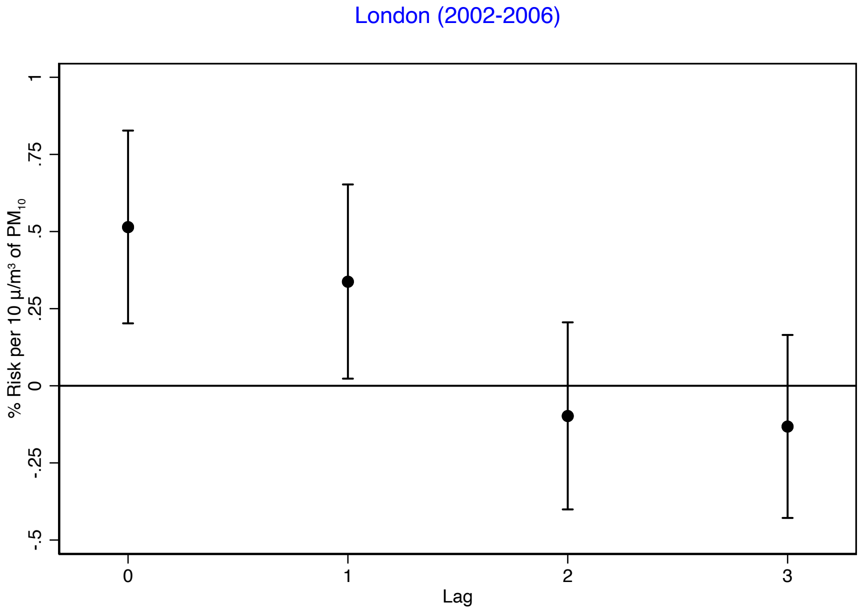
  - $exp(\beta_j)$ is the relative risk (RR) for 1 unit increase of the PM_{10} exposure at $lag \; j$

- First week of time-series data in London (Jan 2002 – Dec 2006)

obs	date	deaths	pm10	lag1. pm10	lag2. pm10
1.	01jan2002	199	71.7	.	.
2.	02jan2002	231	40.2	71.7	.
3.	03jan2002	210	41.8	40.2	71.7
4.	04jan2002	203	50.4	41.8	40.2
5.	05jan2002	224	49.4	50.4	41.8
6.	06jan2002	198	31.1	49.4	50.4
7.	07jan2002	180	48.6	31.1	49.4

Distributed lags





Multi-location studies

Table 1. **Percentage Change in All-Cause Mortality per 10-μg-per-Cubic-Meter Increase in 2-Day Moving Average Concentrations of Inhalable Particulate Matter (PM_{10}) and Fine Particulate Matter ($PM_{2.5}$).***

Country or Region	PM_{10}		$PM_{2.5}$	
	Cities with Available Data	Pooled Estimate	Cities with Available Data	Pooled Estimate
	no.	*% (95% CI)*	*no.*	*% (95% CI)*
Australia	3	1.32 (0.22 to 2.44)	3	1.42 (−0.12 to 2.99)
Brazil	1	1.22 (0.97 to 1.47)	0	NA
Canada	13	0.76 (0.25 to 1.27)	25	1.70 (1.17 to 2.23)
Chile	4	0.33 (0.14 to 0.53)	4	0.27 (−0.68 to 1.23)
China	272	0.28 (0.22 to 0.34)	272	0.41 (0.32 to 0.50)
Colombia	1	0.03 (−0.34 to 0.39)	0	NA
Czech Republic	1	0.40 (−0.02 to 0.82)	0	NA
Estonia	4	0.46 (−0.69 to 1.63)	3	0.23 (−4.24 to 4.90)
Finland	1	0.07 (−0.51 to 0.65)	1	0.14 (−0.55 to 0.83)
France	18	0.46 (−0.15 to 1.07)	0	NA
Greece	1	0.53 (0.17 to 0.90)	1	2.54 (1.28 to 3.83)
Italy	18	0.65 (0.26 to 1.04)	0	NA
Japan	47	1.05 (0.78 to 1.31)	47	1.42 (1.05 to 1.81)
Mexico	8	0.67 (0.48 to 0.86)	3	1.29 (0.21 to 2.39)
Portugal	2	0.11 (−0.27 to 0.49)	1	0.03 (−1.14 to 1.21)
South Africa	6	0.41 (0.14 to 0.68)	5	0.80 (0.16 to 1.44)
South Korea	7	0.42 (0.27 to 0.58)	0	NA
Spain	45	0.87 (0.60 to 1.15)	19	1.96 (1.18 to 2.75)
Sweden	1	0.20 (−1.03 to 1.44)	1	0.08 (−1.44 to 1.62)
Switzerland	8	0.47 (−0.36 to 1.31)	4	0.79 (−0.96 to 2.58)
Taiwan	3	0.25 (−0.03 to 0.53)	3	0.62 (−0.39 to 1.64)
Thailand	19	0.61 (0.24 to 0.99)	0	NA
United Kingdom	15	0.06 (−0.36 to 0.48)	0	NA
United States	100	0.79 (0.60 to 0.98)	107	1.58 (1.28 to 1.88)
Total	598	0.44 (0.39 to 0.50)	499	0.68 (0.59 to 0.77)

* Pooled estimates represent the percentage changes in daily all-cause mortality per 10-μg-per-cubic-meter increase in concentrations of particulate matter (PM) with an aerodynamic diameter of 10 μm or less (PM_{10}) and PM with an aerodynamic diameter of 2.5 μm or less ($PM_{2.5}$), as determined with the use of trimmed exposure data in which the highest 5% and lowest 5% of PM_{10} and $PM_{2.5}$ measurements were excluded. NA denotes not available.

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Ambient Particulate Air Pollution and Daily Mortality in 652 Cities

C. Liu, R. Chen, F. Sera, A.M. Vicedo-Cabrera, Y. Guo, S. Tong, M.S.Z.S. Coelho, P.H.N. Saldiva, E. Lavigne, P. Matus, N. Valdes Ortega, S. Osorio Garcia, M. Pascal, M. Stafoggia, M. Scortichini, M. Hashizume, Y. Honda, M. Hurtado-Díaz, J. Cruz, B. Nunes, J.P. Teixeira, H. Kim, A. Tobias, C. Íñiguez, B. Forsberg, C. Åström, M.S. Ragettli, Y.-L. Guo, B.-Y. Chen, M.L. Bell, C.Y. Wright, N. Scovronick, R.M. Garland, A. Milojevic, J. Kyselý, A. Urban, H. Orru, E. Indermitte, J.J.K. Jaakkola, N.R.I. Ryti, K. Katsouyanni, A. Analitis, A. Zanobetti, J. Schwartz, J. Chen, T. Wu, A. Cohen, A. Gasparrini, and H. Kan

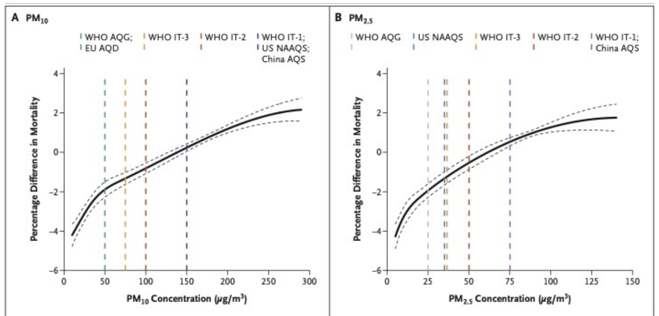
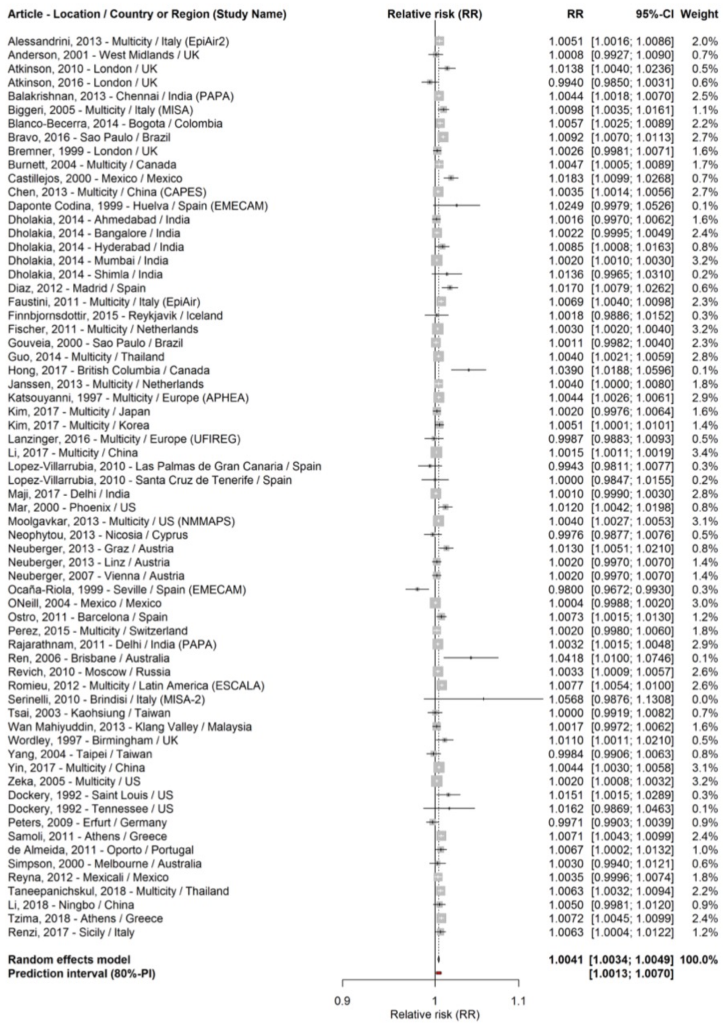


Figure 3. **Pooled Concentration–Response Curves.**

Shown are the pooled concentration–response curves for the associations of 2-day moving average concentrations of PM_{10} (Panel A) and $PM_{2.5}$ (Panel B) with daily all-cause mortality. The y axis represents the percentage difference from the pooled mean effect (as derived from the entire range of PM concentrations at each location) on mortality. Zero on the y axis represents the pooled mean effect, and the portion of the curve below zero denotes a smaller estimate than the mean effect. The dashed lines represent the air-quality guidelines or standards for 24-hour average concentrations of PM_{10} or $PM_{2.5}$ according to the World Health Organization Air Quality Guidelines (WHO AQG), WHO Interim Target 1 (IT-1), WHO Interim Target 2 (IT-2), WHO Interim Target 3 (IT-3), European Union Air Quality Directive (EU AQD), U.S. National Ambient Air Quality Standard (NAAQS), and China Air Quality Standard (AQS).

Figure A.1. Forest plot of 58 studies (66 effect sizes) examining the association between PM_{10} and all-cause mortality.



Literature review

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Review article

Short-term exposure to particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) and all-cause and cause-specific mortality: Systematic review and *meta*-analysis

Pablo Orellano[a,*], Julieta Reynoso[b], Nancy Quaranta[c,d], Ariel Bardach[e], Agustin Ciapponi[e]

Table 1
Exposures, outcomes and pooled effect sizes.

Pollutant	Outcome	Number of effect sizes	RR (95% CI)	p-value	PI	Egger's test (p-value)
PM_{10}	All-cause mortality	66	1.0041 (1.0034–1.0049)	< 0.0001	1.0013–1.0070	< 0.001
PM_{10}	Cardiovascular mortality	44	1.0060 (1.0044–1.0077)	< 0.0001	1.0016–1.0105	0.024
PM_{10}	Respiratory mortality	41	1.0091 (1.0063–1.0119)	< 0.0001	1.0017–1.0166	0.209
PM_{10}	Cerebrovascular mortality	20	1.0044 (1.0022–1.0066)	0.0005	1.0001–1.0087	< 0.001
$PM_{2.5}$	All-cause mortality	29	1.0065 (1.0044–1.0086)	< 0.0001	1.0017–1.0114	0.015
$PM_{2.5}$	Cardiovascular mortality	28	1.0092 (1.0061–1.0123)	< 0.0001	1.0026–1.0158	0.803
$PM_{2.5}$	Respiratory mortality	20	1.0073 (1.0029–1.0116)	0.0023	0.9998–1.0148	0.606
$PM_{2.5}$	Cerebrovascular mortality	7	1.0072 (1.0012–1.0132)	0.0257	0.9953–1.0192	N/A
NO_2 (24-hour average)	All-cause mortality	54	1.0072 (1.0059–1.0085)	< 0.0001	1.0031–1.0113	0.048
NO_2 (1-hour max.)	All-cause mortality	10	1.0024 (0.9995–1.0053)	0.0892	0.9985–1.0064	0.154
O_3	All-cause mortality	48	1.0043 (1.0034–1.0052)	< 0.0001	1.0013–1.0073	0.001

RR, pooled relative risks; 95% CI, 95% confidence interval; p-value, significance of the association or statistical tests; PI, 80% prediction interval; N/A, not applicable (< 10 studies).

Summary

- The time-series design is useful to provide evidence on short-term associations between air pollution and health outcomes
- Time-series regression is similar in principle to any regression analysis but with some specific features
- The design accounts for temporal variations (e.g., seasonal changes, day-of-week effects) and weather conditions (e.g., temperature) that may influence both air pollution and health outcome
- Time-series studies can investigate lagged effects, identifying whether health outcomes occur immediately or with some delay following exposure to air pollution