Training Course on Seamless Prediction of Air Pollution in Africa

Health Impact Assessments

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Deadly smog in London, 1952



Major air pollutants



Health effects of air pollution





Regulatory Concentrations

Table 0.1. Recommended AQG levels and interim targets

Pollutant	Averaging time		Interim target			
		1	2	3	4	-
PM _{2.5} , µg/m ³	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/m ³	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



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.



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Confounding

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Modelling framework

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

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

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

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)×100% is the percentage risk increase





- 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

$$log(Y_t) = \beta_0 + \sum \beta_j P M_{10_{t-j}} + ns(t) + ns(temp)$$

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

				lagl.	1ag2.
obs	date	deaths	pm10	pm10	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	4 0.2
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



Multi-location studies

Fable 1. Percentage Change in All-Cause Mortality per 10+µg-per-Cubic-Meter Increase in 2-Day Moving Average Concentrations of Inhalable Particulate Matter (PM10) and Fine Particulate Matter (PM2.5).*

Country or Region		PM10	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 (PM₁₀) 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 PM₁₀ and PM_{2.5} measurements were excluded. NA denotes not available.



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. Iñiguez, B. Forsberg, C. Åström, M.S. Ragettil, 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 PM₁₂ (Panel A) and PM₂₂ (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 PM₂₀, represents the tot PM₂₀ according to the World Health Organization Air Quality Guidelines (WHO AQG), WHO Interim Target 1 (T-1), WHO Interim Target 2 (T-2), WHO Interim Target 3 (T-3), European Union Air Quality Directive (EU AQD). U.S. National Ambient Air Quality Clarketty (EU AQD).

Figure A.1. Forest plot of 58 studies (66 effect sizes) examining the association between PM₁₀ and all-cause mortality.

Article - Location / Country or Region (Study Name)	Relative ris	k (RR) RR	95%-CI	Weight
Alessandrini, 2013 - Multicity / Italy (EpiAir2)	<u>i</u>	1.0051	[1.0016; 1.0086]	2.0%
Anderson, 2001 - West Midlands / UK	Ť	1.0008	[0.9927; 1.0090]	0.7%
Atkinson, 2010 - London / UK		⊢ 1.0138	[1.0040; 1.0236]	0.5%
Atkinson, 2016 - London / UK		0.9940	[0.9850; 1.0031]	0.6%
Balakrishnan, 2013 - Chennai / India (PAPA)		1.0044	[1.0018; 1.0070]	2.5%
Biggeri, 2005 - Multicity / Italy (MISA)		1.0098	[1.0035; 1.0161]	1.1%
Blanco-Becerra, 2014 - Bogota / Colombia	100	1.0057	[1.0025; 1.0089]	2.2%
Bravo, 2016 - Sao Paulo / Brazil		1.0092	[1.0070; 1.0113]	2.7%
Bremner, 1999 - London / UK	亡	1.0026	[0.9981; 1.0071]	1.6%
Burnett, 2004 - Multicity / Canada		1.0047	[1.0005; 1.0089]	1.7%
Castillejos, 2000 - Mexico / Mexico	<u> </u>	- 1.0183	[1.0099; 1.0268]	0.7%
Chen, 2013 - Multicity / China (CAPES)	11	1.0035	[1.0014; 1.0056]	2.1%
Daponte Codina, 1999 - Hueiva / Spain (EMECAM)	1	1.0249	[0.9979; 1.0526]	0.1%
Dholakia, 2014 - Anmedabad / India	<u>T.</u>	1.0016	[0.9970; 1.0062]	1.0%
Dholakia, 2014 - Bangalore / India	E.	1.0022	[0.9995; 1.0049]	2.4%
Dholakia, 2014 - Hyderabad / India	1.00	1.0085	[1.0008, 1.0183]	0.0%
Dholakia, 2014 - Mumbal / India	I	1.0020	[1.0010, 1.0030]	0.2%
Diora 2012 Madrid / Engin		1.0130	[0.9905, 1.0310]	0.2%
Eaustini, 2012 - Madrid / Spain Eaustini, 2011 - Multicity / Italy /EpiAir)	100	1.0170	[1.0079, 1.0202]	2 304
Fighting 2011 - Multicity / Italy (EpiAli)	5	1.0005	[1.0040, 1.0050]	0.3%
Finitionisuolar, 2013 - Reykjavik / Iceland	6	1.0010	[1 0020: 1 0040]	3 2%
Couvein 2000 - Sao Baulo / Prazil	100	1.0030	[1.0020, 1.0040]	3.270
Guo 2014 - Multicity / Thailand	16	1.0011	[0.9982, 1.0040]	2.3%
Hong 2017 - British Columbia / Canada	1	1.0040	[1.0021, 1.0009]	0.1%
Jansson, 2013 - Multicity / Netherlands		1.0030	[1.0100, 1.0030]	1.8%
Katsouvanni 1997 - Multicity / Europe (APHEA)	- E	1.0040	[1.0026; 1.0060]	2.9%
Kim 2017 - Multicity / Janan	- <u>F</u>	1.0020	[0.9976: 1.0064]	1.6%
Kim, 2017 - Multicity / Korea	E.	1.0020	[1.0001: 1.0101]	1.4%
Lanzinger 2016 - Multicity / Europe (LEIREG)		0.9987	[0.0883: 1.0003]	0.5%
Li 2017 - Multicity / China	1:	1 0015	[1 0011: 1 0019]	3.4%
Lopez-Villarrubia, 2010 - Las Palmas de Gran Canaria / Snain		0.9943	[0.9811: 1.0077]	0.3%
Lopez-Villarrubia, 2010 - Santa Cruz de Tenerife / Snain		1 0000	[0.9847: 1.0155]	0.2%
Maji 2017 - Delhi / India	1	1 0010	[0.9990: 1.0030]	2.8%
Mar. 2000 - Phoenix / US	1.	- 1.0120	[1.0042: 1.0198]	0.8%
Moolgaykar, 2013 - Multicity / US (NMMAPS)	10	1.0040	[1.0027: 1.0053]	3.1%
Neophytou, 2013 - Nicosia / Cyprus	-4	0.9976	[0.9877: 1.0076]	0.5%
Neuberger, 2013 - Graz / Austria		⊢ 1.0130	[1.0051: 1.0210]	0.8%
Neuberger, 2013 - Linz / Austria	÷	1.0020	[0.9970; 1.0070]	1.4%
Neuberger, 2007 - Vienna / Austria	¥	1.0020	[0.9970; 1.0070]	1.4%
Ocaña-Riola, 1999 - Seville / Spain (EMECAM)		0.9800	[0.9672; 0.9930]	0.3%
ONeill, 2004 - Mexico / Mexico		1.0004	[0.9988; 1.0020]	3.0%
Ostro, 2011 - Barcelona / Spain	*	1.0073	[1.0015; 1.0130]	1.2%
Perez, 2015 - Multicity / Switzerland		1.0020	[0.9980; 1.0060]	1.8%
Rajarathnam, 2011 - Delhi / India (PAPA)	10	1.0032	[1.0015; 1.0048]	2.9%
Ren, 2006 - Brisbane / Australia		1.0418	[1.0100; 1.0746]	0.1%
Revich, 2010 - Moscow / Russia	10	1.0033	[1.0009; 1.0057]	2.6%
Romieu, 2012 - Multicity / Latin America (ESCALA)	101	1.0077	[1.0054; 1.0100]	2.6%
Serinelli, 2010 - Brindisi / Italy (MISA-2)		1.0568	[0.9876; 1.1308]	0.0%
Tsai, 2003 - Kaohsiung / Taiwan	+	1.0000	[0.9919; 1.0082]	0.7%
Wan Mahiyuddin, 2013 - Klang Valley / Malaysia	世	1.0017	[0.9972; 1.0062]	1.6%
Wordley, 1997 - Birmingham / UK	*	- 1.0110	[1.0011; 1.0210]	0.5%
Yang, 2004 - Taipei / Taiwan	亡	0.9984	[0.9906; 1.0063]	0.8%
Yin, 2017 - Multicity / China		1.0044	[1.0030; 1.0058]	3.1%
Zeka, 2005 - Multicity / US		1.0020	[1.0008; 1.0032]	3.2%
Dockery, 1992 - Saint Louis / US	-	► 1.0151	[1.0015; 1.0289]	0.3%
Dockery, 1992 - Tennessee / US		• 1.0162	[0.9869; 1.0463]	0.1%
Peters, 2009 - Erfurt / Germany	1.	0.9971	[0.9903; 1.0039]	0.9%
Samoli, 2011 - Athens / Greece	100	1.0071	[1.0043; 1.0099]	2.4%
de Almeida, 2011 - Oporto / Portugal		1.0067	[1.0002; 1.0132]	1.0%
Simpson, 2000 - Melbourne / Australia	Ē.	1.0030	[0.9940; 1.0121]	0.6%
reyna, 2012 - mexicali / Mexico	12	1.0035	[0.9996; 1.0074]	1.8%
Laneepanichskui, 2018 - Multicity / Thailand	100	1.0063	[1.0032; 1.0094]	2.2%
Li, 2018 - Ningbo / China		1.0050	[0.9981; 1.0120]	0.9%
Izima, 2016 - Attens / Greece	1	1.0072	[1.0045; 1.0099]	2.4%
Renzi, 2017 - Sicily / Italy	*	1.0063	[1.0004; 1.0122]	1.2%
Pandom offests model		4 0044	14 0024. 4 00403	100.0%
Radiation interval (20% PI)	•	1.0041	[1.0034; 1.0049]	100.0%
Prediction Interval (80%-PI)			[1.0013; 1.0070]	
0.9	1	11		
0.9	Relative risk	k (BR)		

Literature review



a Central Control Cont

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.

F								
Pollutant	Outcome	Number of effect sizes	RR (95% CI)	p-value	Ы	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	< 0.0001	1.0031-1.0113	0.048		
NO ₂ (1-hour max.)	All-cause mortality	10	1.0024	0.0892	0.9985-1.0064	0.154		
O ₃	All-cause mortality	48	1.0043	< 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-ofweek 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