Epidemiology of NO$_2$, PM$_{10}$ and PM$_{2.5}$ in Wales

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Background

Particulate matter (PM)	Nitrogen dioxide (NO$_2$)
▪ Inhaled particles <10μm in diameter (PM$_{10}$ 'thoracic' fraction) penetrate, and deposit in, the upper respiratory tract. ▪ Fine PM$_{2.5}$ 'respirable' fraction penetrate deeper into lung alveoli. ▪ Both cause lung lining inflammation which places pressure on, and affects the function of, various body systems. ▪ Chronic exposure increases morbidity and mortality risk through cardiovascular and respiratory impacts. ▪ Exposure also linked with atherosclerosis, childhood respiratory disease, endocrine (diabetes) and nervous (cognitive function) system impacts, birth outcomes, liver and kidney damage. ▪ Diesel exhaust and particulate air pollution is carcinogenic to humans.	▪ Exposure causes airway inflammation and impaired lung function. ▪ Positive and significant short-term associations have been reported with all-cause and cause-specific mortality. ▪ Associations believed not to be confounded by the presence of most particulate matter metrics, especially vehicle emissions. ▪ Evidence suggests stronger, likely causal, relationships between NO$_2$ and adverse health impacts, particularly respiratory effects and linked hospital admissions, but less-so cardiovascular morbidity. ▪ There is some support, but not to the same degree as for short-term exposure, for the relationship to remain causal for chronic exposure to NO$_2$.

Health burden

- PM$_{2.5}$: 29,000 deaths; 307,000 lost life-years

- NO$_2$: 23,500 deaths; 277,000 lost life-years

Pollutant metric	Health outcome	Pollutant range	Concentration Response Function per 10μg/m³ (95%CI)	All-Wales Relative Risk (95% CI)	Annual attributable deaths estimate (95% CI)	Annual estimate Years of Life Lost (95% CI)
NO$_2$ (annual mean)	All-cause mortality (natural), age 30+ years	>20μg/m³	1.055 (1.031 to 1.080)	1.16 (1.09 to 1.23)	**1,328** (747 to 1908)	**15,936** (8,964 to 22,896)
PM$_{10}$ (annual mean)	All-cause mortality (natural), all ages	All	1.035 (1.004 to 1.066)	1.05 (1.01 to 1.10)	**1,502** (300 to 2,703)	**18,024** (3,600 to 32,436)
PM$_{2.5}$ (annual mean)	All-cause mortality (natural), age 30+ years	All	1.062 (1.040 to 1.083)	1.06 (1.04 to 1.08)	**1,791** (1,194 to 2,388)	**21,492** (14,328 to 28,656)

- 7-8 months life expectancy reduction for every UK resident
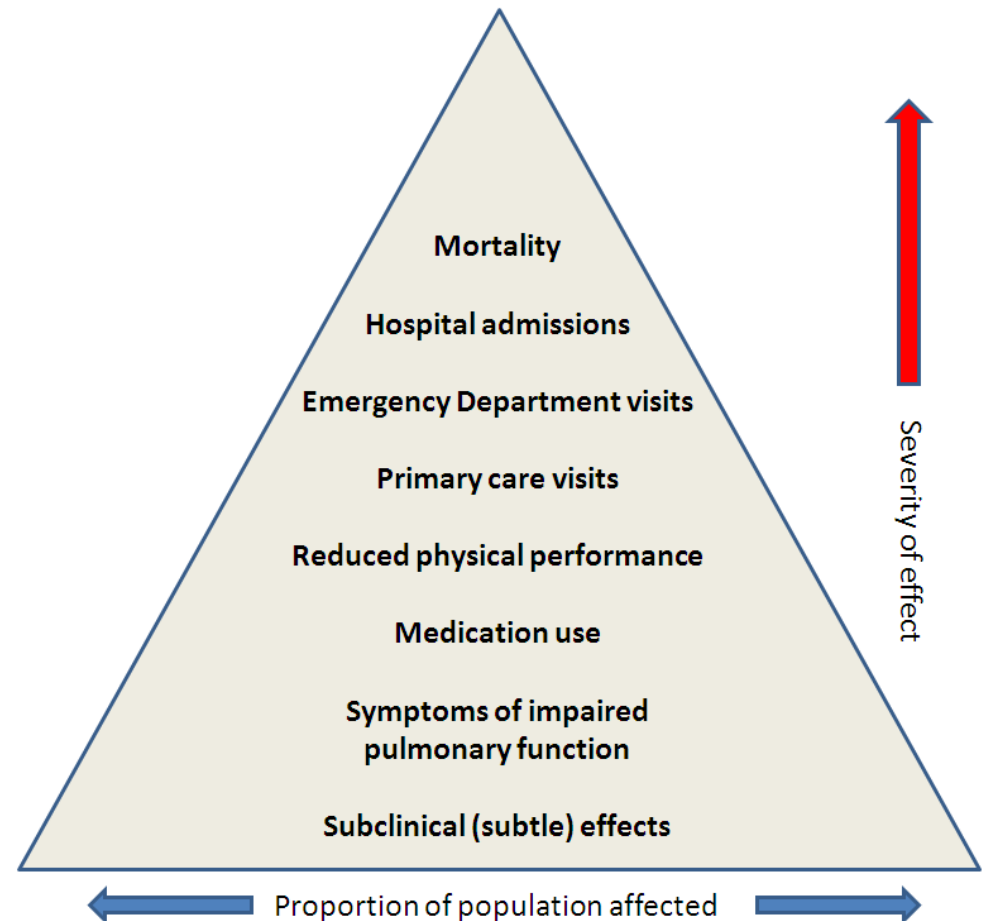
Economic costs of health impacts

- Value of statistical life (2010) = $3.55M or £2.35m

- Estimated annual cost of attributable mortality

$$NO_2 \quad = \quad £3.12b$$
$$PM_{10} \quad = \quad £3.53b$$
$$PM_{2.5} \quad = \quad £4.21b$$

- Tip of the iceberg...

Mortality

Hospital admissions

Emergency Department visits

Primary care visits

Reduced physical performance

Medication use

Symptoms of impaired pulmonary function

Subclinical (subtle) effects

Severity of effect

Proportion of population affected

Source: Craig L, Brook JR, Chiotti Q, Croes B, Gower S *et al.*, (2008a). Air pollution and public health: a guidance document for risk managers. *Journal of Toxicology and Environmental Health, Part A*; 71: 588-698.

TABLE 2 Wales: baseline population, modelled population-weighted mean concentrations (μg m^{-3}) and estimated effects on annual mortality in 2010 of anthropogenic $PM_{2.5}$ air pollution

Area	Population age 25+ (x 10³)	Deaths age 25+	Mean anthropogenic $PM_{2.5}$ (μg m^{-3})*	Attributable fraction[†] (%)	Attributable deaths[‡] age 25+	Associated life-years lost[§]
WALES	**2075.4**	**31041**	**7.5**	**4.3**	**1320**	**13549**
Betsi Cadwaladr LHB	481.6	7462	6.7	3.8	280	2836
Isle of Anglesey	49.4	815	5.5	3.2	26	251
Gwynedd	81.2	1347	5.5	3.1	42	408
Conwy	81.6	1479	6.0	3.4	51	489
Denbighshire	69.6	1154	6.4	3.7	42	422
Flintshire	106.1	1366	8.0	4.5	62	670
Wrexham	93.5	1301	7.6	4.3	56	595
Powys LHB	96.5	1445	6.2	3.6	51	509
Powys	96.5	1445	6.2	3.6	51	509
Hywel Dda LHB	264.5	4190	6.6	3.7	157	1562
Ceredigion	51.8	745	5.8	3.3	25	273
Pembrokeshire	83.8	1347	6.6	3.8	51	500
Carmarthenshire	128.8	2098	6.9	3.9	82	789
Abertawe Bro Morgannwg LHB	349.0	5362	7.4	4.2	227	2314
Swansea	157.1	2405	7.4	4.2	102	1048
Neath Port Talbot	97.3	1573	7.4	4.2	66	662
Bridgend	94.6	1385	7.5	4.3	59	604
Cardiff and Vale LHB	299.1	3843	9.0	5.1	196	2100
Vale of Glamorgan	86.5	1190	7.9	4.5	53	557
Cardiff	212.6	2653	9.5	5.4	143	1543
Cwm Taf LHB	198.5	3081	7.7	4.4	135	1399
Rhondda, Cynon, Taff	160.4	2491	7.8	4.4	110	1130
Merthyr Tydfil	38.1	590	7.5	4.3	25	269
Aneurin Bevan LHB	386.4	5658	8.5	4.8	273	2829
Caerphilly	118.7	1687	8.3	4.7	80	822
Blaenau Gwent	47.4	797	7.9	4.5	36	356
Torfaen	62.8	951	8.5	4.8	46	473
Monmouthshire	63.6	874	7.9	4.5	39	404
Newport	93.8	1350	9.4	5.4	72	774

Attributable mortality fraction between 3-5% in Wales

Limitations

- Useful profile and scope
- Mask small-area variations in levels, risks and impacts
- Local influences on air pollution concentrations

- Not just differential exposures that influence risks/impacts
- Individual and population-level susceptibilities

"Intrinsic"   age, sex, genetics, ethnicity
"Acquired"   income, education, housing, employment,
                  service access, chronic illness, lifestyle/behaviours

TRIPLE JEOPARDY

Study aim and objectives

Aim	*To assess local air pollution, deprivation and health associations in Wales*
Objectives	*To determine any added value of:* 1. *considering local air pollution problems and solutions in a broader public health context* 2. *Increasing Public Health integration and engagement in local air quality assessment and management*

Methods

Data		
Data	Geography	Lower Super Output Areas (LSOA) - Wales
	Air pollution	Modelled population-weighted 3-year (2011 to 2013) averaged annual mean concentrations for NO_2, PM_{10}, $PM_{2.5}$
	Health	All-cause mortality; Cardiovascular, cerebrovascular, respiratory and chronic liver disease mortality and morbidity
	Deprivation	Welsh Index of Multiple Deprivation – Income Deprivation

| Analysis		
Analysis	Variation	Data linked and mapped at local level. Air pollution and deprivation status assigned to LSOAs.
	Associations	Separate *air pollution-health* and *deprivation-health analyses.* Air pollution and deprivation interactions; combined association with health outcomes.

Results

a)
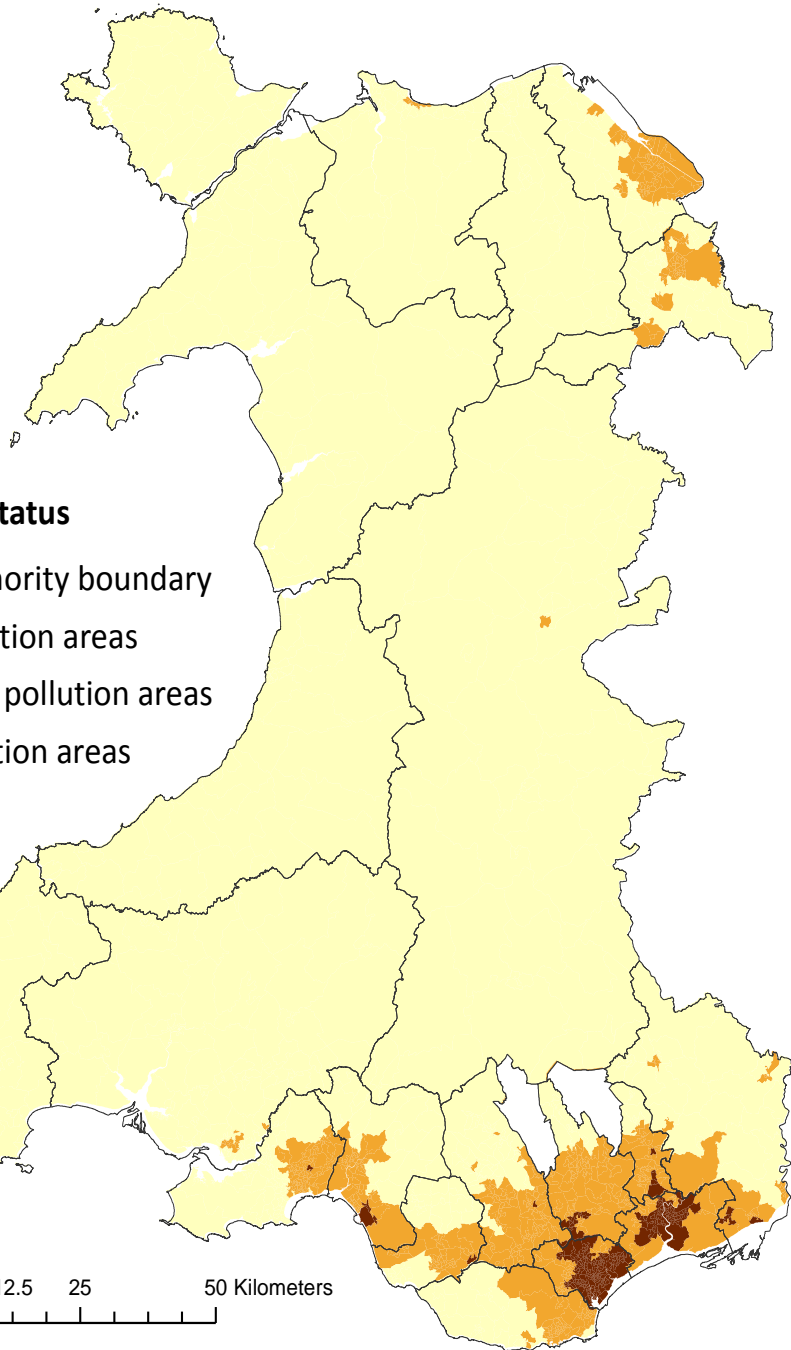
NO₂ pollution status

- ☐ Local Authority boundary
- ■ High pollution areas
- ■ Moderate pollution areas
- ■ Low pollution areas
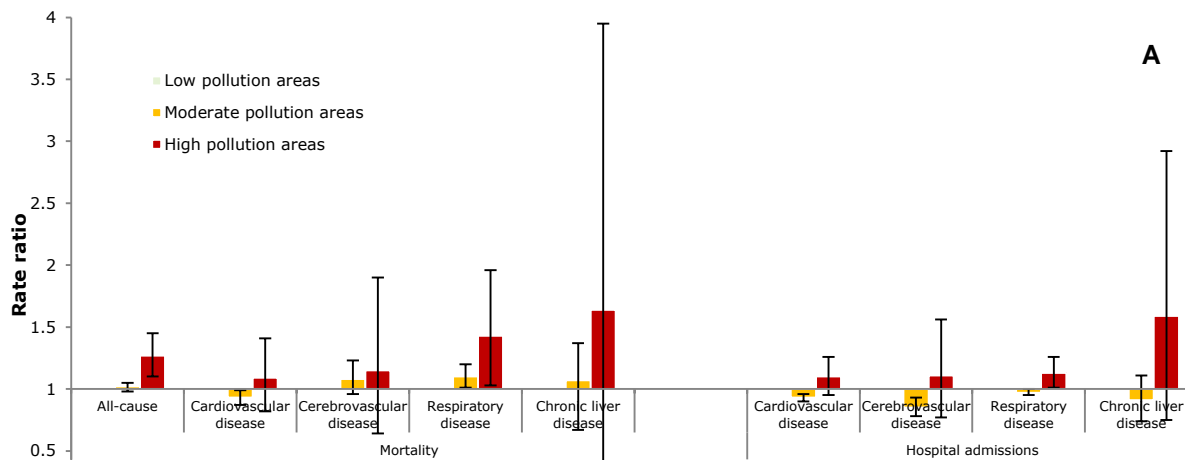
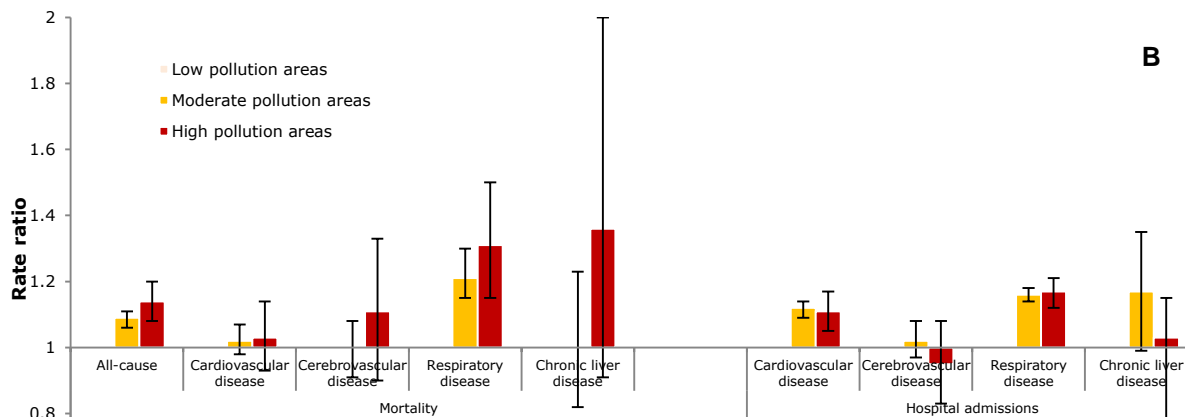0   12.5   25   50 Kilometers

b)
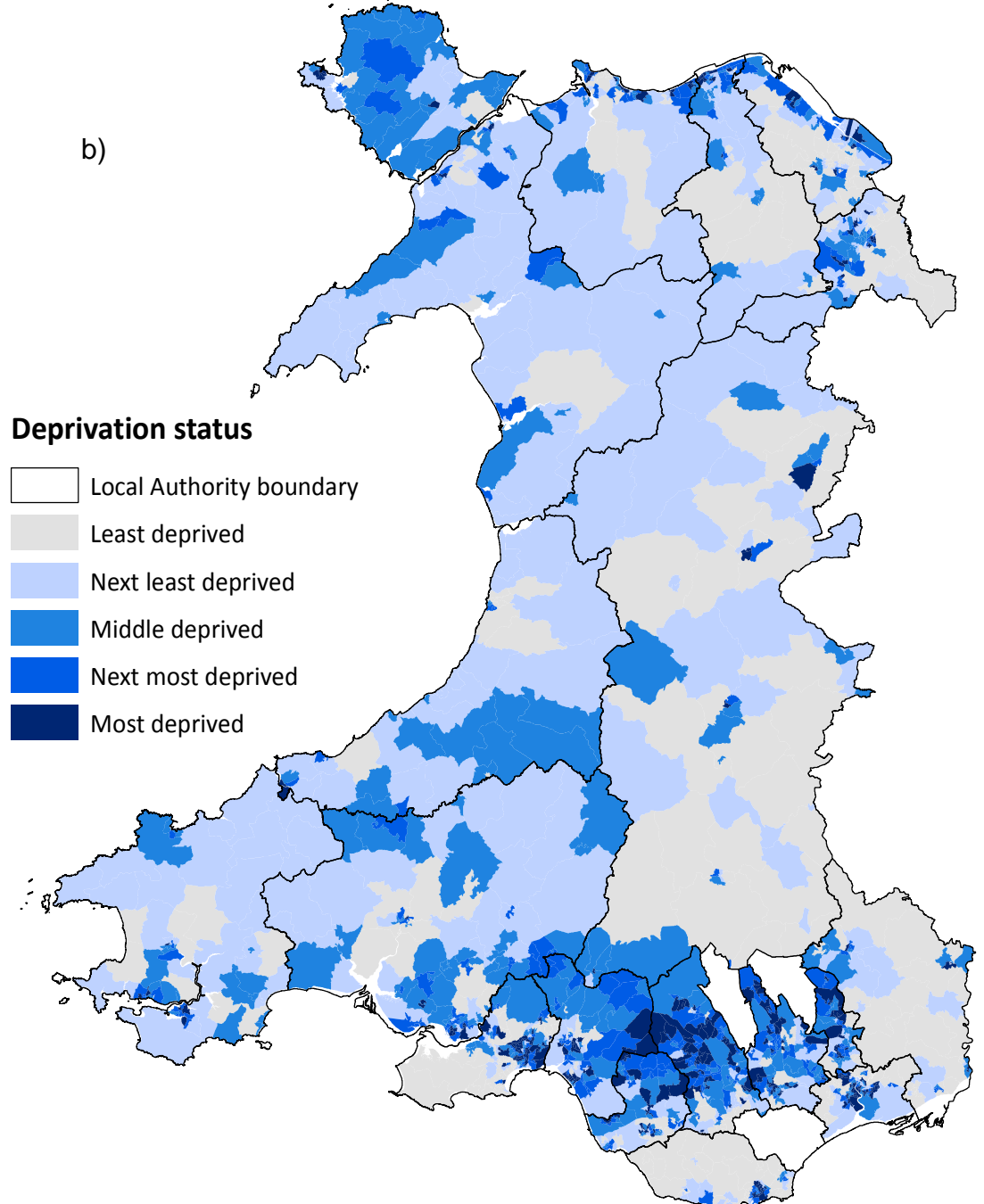
Deprivation status

- ☐ Local Authority boundary
- ■ Least deprived
- ■ Next least deprived
- ■ Middle deprived
- ■ Next most deprived
- ■ Most deprived

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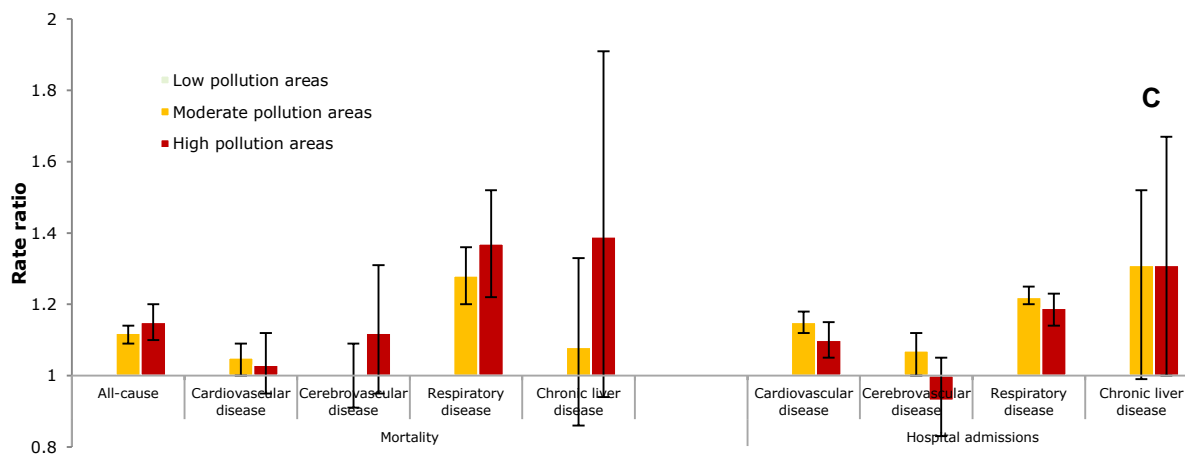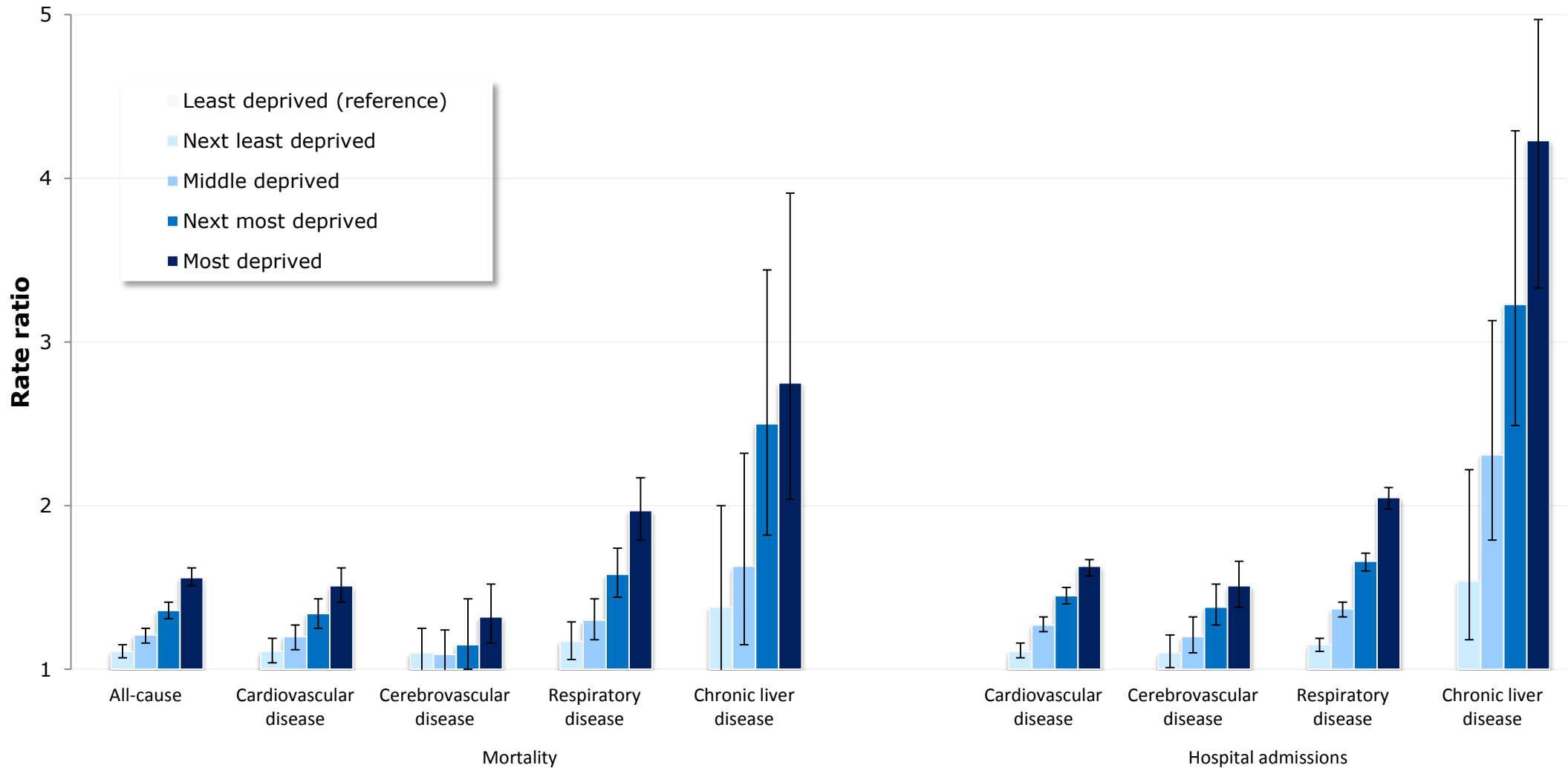
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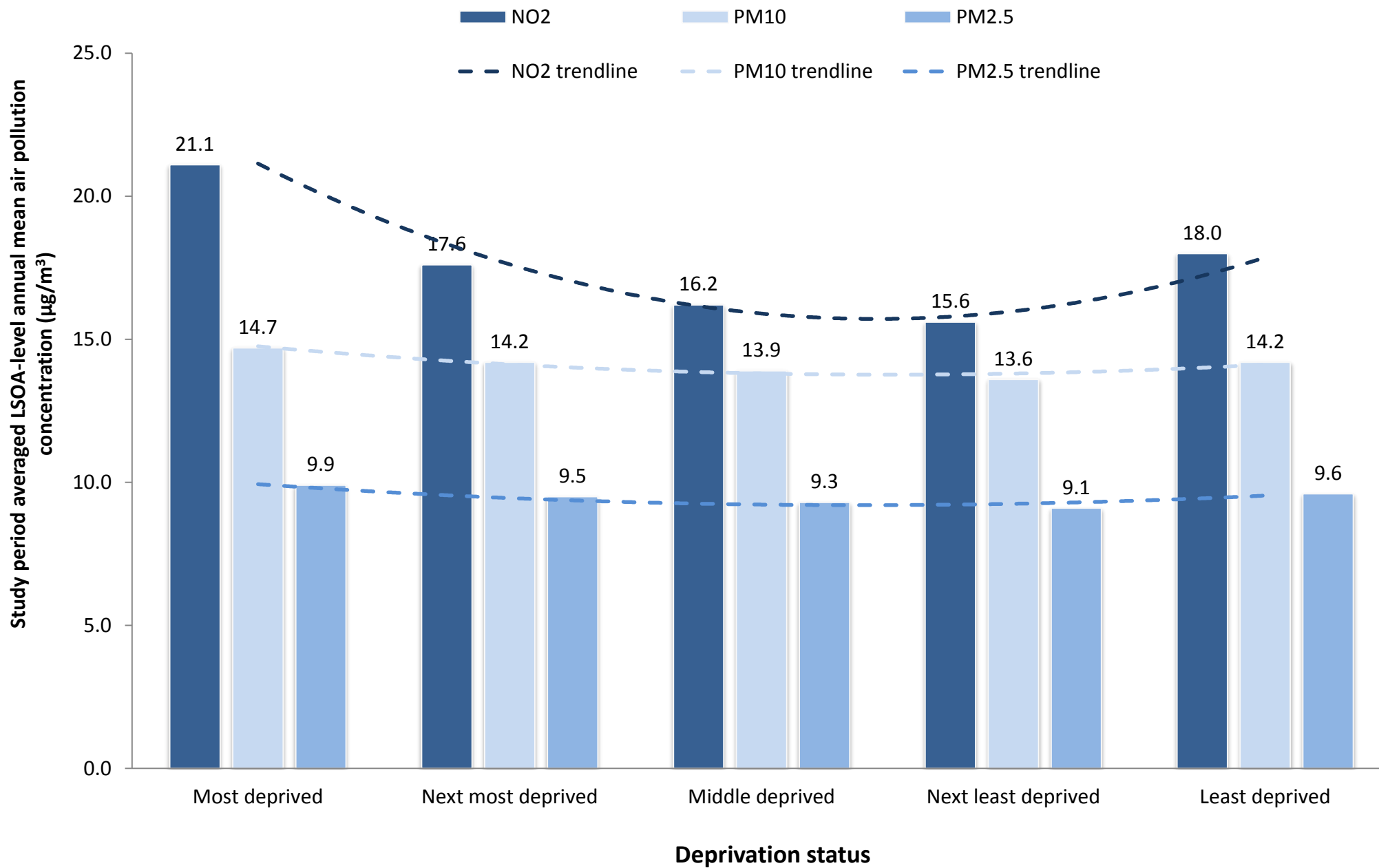
NO₂: all-cause and respiratory disease mortality

B

PM₁₀: all-cause and respiratory disease mortality; cardiovascular disease and respiratory morbidity

C

PM₂.₅: all-cause and respiratory disease mortality; cardiovascular disease and respiratory morbidity

Deprivation-health association

- Evidence of strong positive associations
- Rates of all health outcomes ↑ as deprivation levels ↑
- All health outcome rates (except cerebrovascular mortality) significantly higher

Air pollution-deprivation-health association

			Deprivation status	Air pollution status		
				Low	Moderate	High
Nitrogen dioxide (NO₂)	Mortality rate ratio (95%CI)	All-cause	Least	-	1.01 (0.92 to 1.07)	1.09 (0.28 to 2.09)
			Most	1.41* (1.36 to 1.45)	1.43* (1.34 to 1.52)	1.62* (1.37 to 1.89)
		Cardiovascular disease	Least	-	0.94 (0.84 to 1.06)	1.17 (0.03 to 3.95)
			Most	1.40* (1.32 to 1.48)	1.26* (1.14 to 1.40)	1.32 (0.93 to 1.78)
		Cerebrovascular disease	Least	-	1.04 (0.83 to 1.27)	0.41 (0.01 to 2.84)
			Most	1.15* (1.03 to 1.29)	1.31* (1.05 to 1.59)	1.39 (0.67 to 2.44)
		Respiratory disease	Least	-	1.14 (0.97 to 1.32)	1.17 (0.04 to 15.94)
			Most	1.70* (1.57 to 1.84)	1.80* (1.58 to 2.06)	2.10* (1.38 to 3.03)
		Chronic liver disease	Least	-	1.00 (0.54 to 1.88)	0.67 (0.22 to 4.58)
			Most	2.33* (1.81 to 3.17)	2.33* (1.49 to 3.62)	3.56 (0.88 to 8.94)
	Morbidity rate ratio (95%CI)	Cardiovascular disease	Least	-	0.92 (0.86 to 0.98)	1.05 (0.24 to 2.22)
			Most	1.51* (1.47 to 1.56)	1.39* (1.31 to 1.47)	1.44* (1.20 to 1.69)
		Cerebrovascular disease	Least	-	0.80* (0.68 to 0.94)	0.95 (0.01 to 6.81)
			Most	1.42* (1.32 to 1.53)	1.22* (1.05 to 1.39)	1.37 (0.87 to 2.05)
		Respiratory disease	Least	-	0.92 (0.87 to 0.97)	1.02 (0.11 to 1.65)
			Most	1.80* (1.75 to 1.85)	1.73* (1.66 to 1.80)	1.70* (1.49 to 1.93)
		Chronic liver disease	Least	-	0.75 (0.42 to 1.25)	0.81 (0.13 to 6.44)
			Most	3.25* (2.66 to 4.11)	2.69* (1.96 to 3.71)	4.13* (1.79 to 8.24)
Particulate matter (PM₁₀)	Mortality rate ratio (95%CI)	All-cause	Least	-	1.02 (0.96 to 1.08)	1.06 (0.91 to 1.24)
			Most	1.56* (1.46 to 1.66)	1.58* (1.50 to 1.66)	1.65* (1.50 to 1.80)
		Cardiovascular disease	Least	-	0.95 (0.86 to 1.05)	1.05 (0.78 to 1.38)
			Most	1.54* (1.37 to 1.73)	1.46* (1.33 to 1.61)	1.38* (1.16 to 1.64)
		Cerebrovascular disease	Least	-	1.02 (0.82 to 1.24)	1.21 (0.68 to 1.96)
			Most	1.33* (1.04 to 1.68)	1.36* (1.11 to 1.64)	1.33 (0.91 to 1.87)
		Respiratory disease	Least	-	1.19* (1.02 to 1.39)	1.35 (0.86 to 1.95)
			Most	2.05* (1.73 to 2.41)	2.21* (1.92 to 2.53)	2.38* (1.89 to 2.95)
		Chronic liver disease	Least	-	1.14 (0.60 to 2.17)	1.57 (0.28 to 5.50)
			Most	3.71* (2.07 to 7.16)	2.71* (1.62 to 5.04)	4.71* (2.32 to 9.79)
	Morbidity rate ratio (95%CI)	Cardiovascular disease	Least	-	1.04 (0.98 to 1.10)	1.03 (0.8 to 1.20)
			Most	1.65* (1.55 to 1.76)	1.68* (1.60 to 1.77)	1.57* (1.43 to 1.72)
		Cerebrovascular disease	Least	-	0.97 (0.85 to 1.11)	0.93 (0.61 to 1.35)
			Most	1.58* (1.35 to 1.84)	1.48* (1.30 to 1.68)	1.31* (1.03 to 1.66)
		Respiratory disease	Least	-	1.04 (0.98 to 1.09)	0.96 (0.84 to 1.09)
			Most	2.03* (1.92 to 2.15)	2.11* (2.01 to 2.21)	2.02* (1.88 to 2.18)
		Chronic liver disease	Least	-	1.08 (0.70 to 1.82)	0.83 (0.16 to 2.82)
			Most	5.17* (3.39 to 8.16)	4.58* (3.12 to 7.01)	3.92 (0.22 to 6.84)
Particulate matter (PM₂.₅)	Mortality rate ratio (95%CI)	All-cause	Least	-	1.04 (0.98 to 1.10)	1.08 (0.91 to 1.18)
			Most	1.57* (1.49 to 1.70)	1.58* (1.50 to 1.67)	1.61* (1.48 to 1.74)
		Cardiovascular disease	Least	-	0.96 (0.87 to 1.07)	0.97 (0.79 to 1.18)
			Most	1.57* (1.38 to 1.78)	1.48* (1.34 to 1.63)	1.40* (1.20 to 1.62)
		Cerebrovascular disease	Least	-	1.05 (0.86 to 1.29)	1.11 (0.74 to 1.59)
			Most	1.41* (1.07 to 1.84)	1.33* (1.09 to 1.63)	1.50* (1.09 to 2.01)
		Respiratory disease	Least	-	1.21 (1.04 to 1.42)	1.26 (0.89 to 1.60)
			Most	2.15* (1.79 to 2.59)	2.19* (1.90 to 2.53)	2.34* (1.91 to 2.85)
		Chronic liver disease	Least	-	1.14 (0.60 to 2.08)	1.43 (0.40 to 4.09)
			Most	4.29* (2.33 to 8.30)	2.86* (1.67 to 5.20)	3.71* (1.92 to 7.50)
	Morbidity rate ratio (95%CI)	Cardiovascular disease	Least	-	1.05 (0.99 to 1.11)	0.95 (0.77 to 1.06)
			Most	1.60* (1.48 to 1.72)	1.71* (1.62 to 1.80)	1.56* (1.44 to 1.69)
		Cerebrovascular disease	Least	-	0.99 (0.86 to 1.13)	0.79 (0.59 to 1.06)
			Most	1.54* (1.29 to 1.83)	1.50* (1.32 to 1.71)	1.76* (1.46 to 2.12)
		Respiratory disease	Least	-	1.06 (1.01 to 1.12)	0.94 (0.85 to 1.04)
			Most	2.03* (1.91 to 2.15)	2.14 * (2.04 to 2.24)	2.04* (1.91 to 2.18)
		Chronic liver disease	Least	-	1.17 (0.72 to 1.88)	0.83 (0.63 to 1.88)
			Most	4.75* (2.99 to 7.67)	4.58* (3.15 to 7.05)	4.58* (2.86 to 7.56)

		Air pollution status		
	Dep	Low	Moderate	High
Respiratory disease mortality	Least	-	**1.19*** (1.02 to 1.39)	**1.35** (0.86 to 1.95)
	Most	**2.05*** (1.73 to 2.41)	**2.21*** (1.92 to 2.53)	**2.38*** (1.89 to 2.95)

Conclusion

- Significant air pollution-related health burden and costs
  National *vs.* regional *vs.* local
- Air pollution, deprivation status and health inextricably linked
- Interactions can modify and amplify associations
- Mixed approach: exposure reduction and targeted action (local problems and solutions considered in broad public health context)
- Maximise health gain and reduce inequalities
- Greater Public Health integration in local air quality assessment and management policy and practice required

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- Limitations – ecological study, modelled data, income deprivation, confounders, simple statistical methods

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