Columbia Climate and Health Program
at the Mailman School of Public Health

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BLACK CARBON: PERPETRATOR OR INDICATOR?

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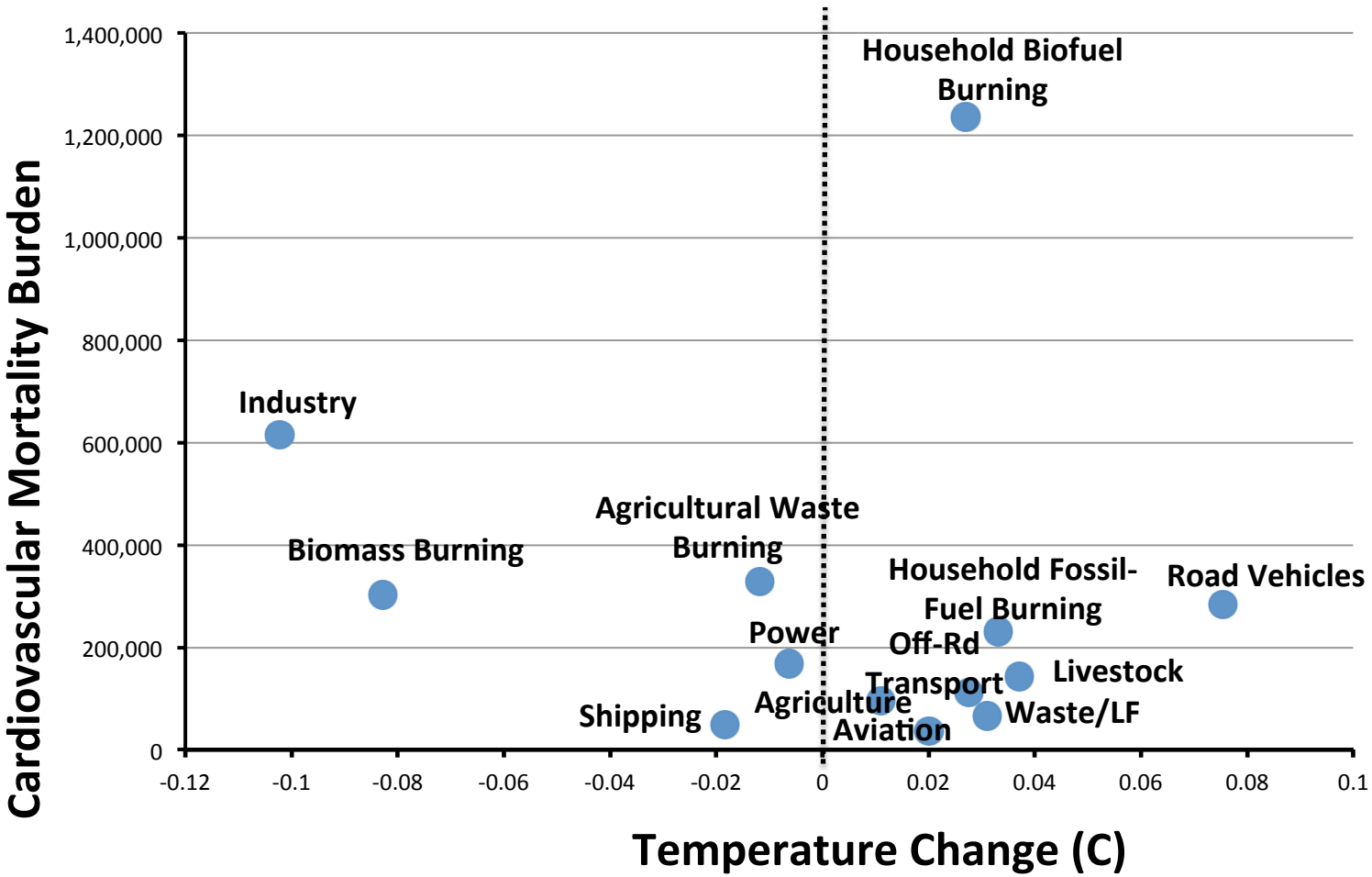
Global scale assessment of PM2.5-related cardiovascular deaths deaths vs. climate warming potential in 2020



Sarma, Jack, Unger, and Kinney, manuscript in prep.

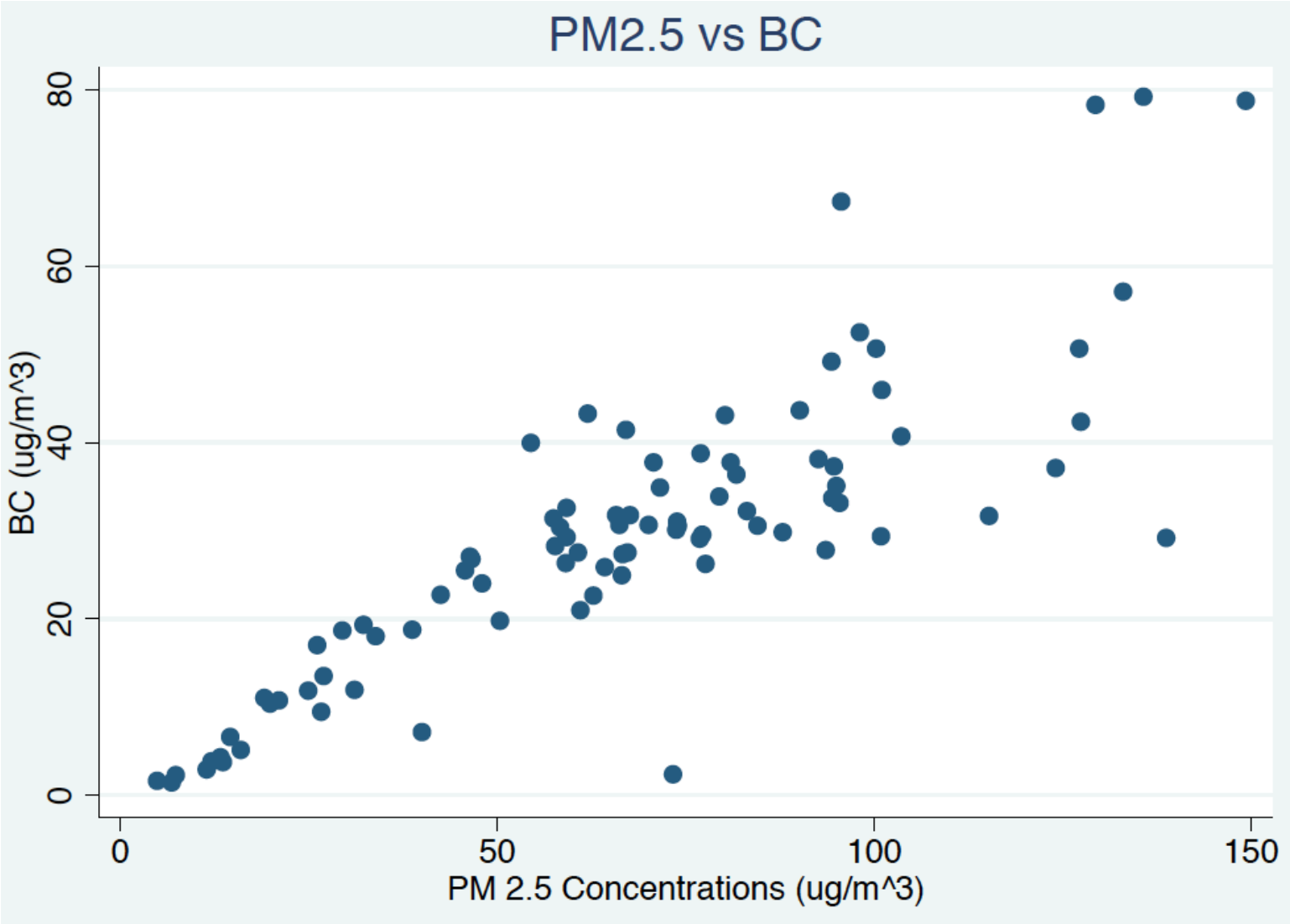

Black carbon sources
in rural Ghana


Black carbon sources in urban Ghana

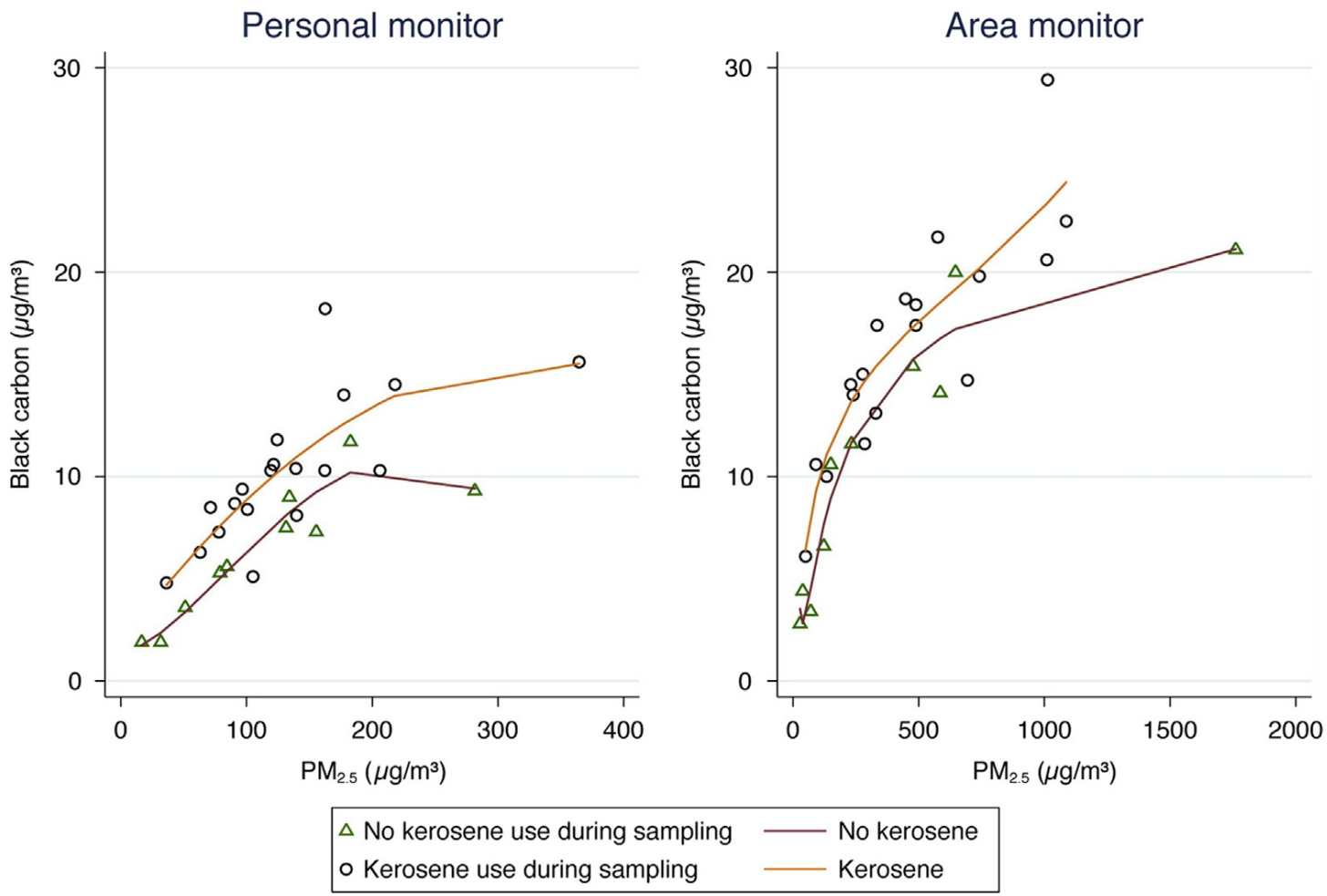
BC and Health

- Epidemiology studies of ambient air have examined relative potency of $PM_{2.5}$, BC and other PM components.
- BC is among the most potent, and robust, PM metrics in these studies, especially for cardiovascular effects.
- Expressed as risk per interquartile range of pollutant, $PM_{2.5}$ and BC risks are similar; however BC has 7-10 x higher risk per $\mu g/m^3$.
- Toxicology studies of pure BC tend not to see substantial effects, implying that BC in the real world travels with other key components that confer health risk.
- $PM_{2.5}$ and BC tend to be well correlated.

Data from sidewalk sampling in Nairobi, summer 2009



BC vs. $PM_{2.5}$ from personal and kitchen area sampling in rural Ghana



Personal exposures to fine particulate matter and black carbon in households cooking with biomass fuels in rural Ghana

Eleanne D.S. Van Vliet [a,*], Kwakupoku Asante [b], Darby W. Jack [a], Patrick L. Kinney [a], Robin M. Whyatt [a], Steven N. Chillrud [c], Livesy Abokyi [b], Charles Zandoh [b], Seth Owusu-Agyei [b]

Environmental Research 127 (2013) 40–48

Time series analysis of hospital admissions vs. PM components, pooled over 119 US Counties, 2000-2008

(source: Levy et al. Amer J Epid 2012)

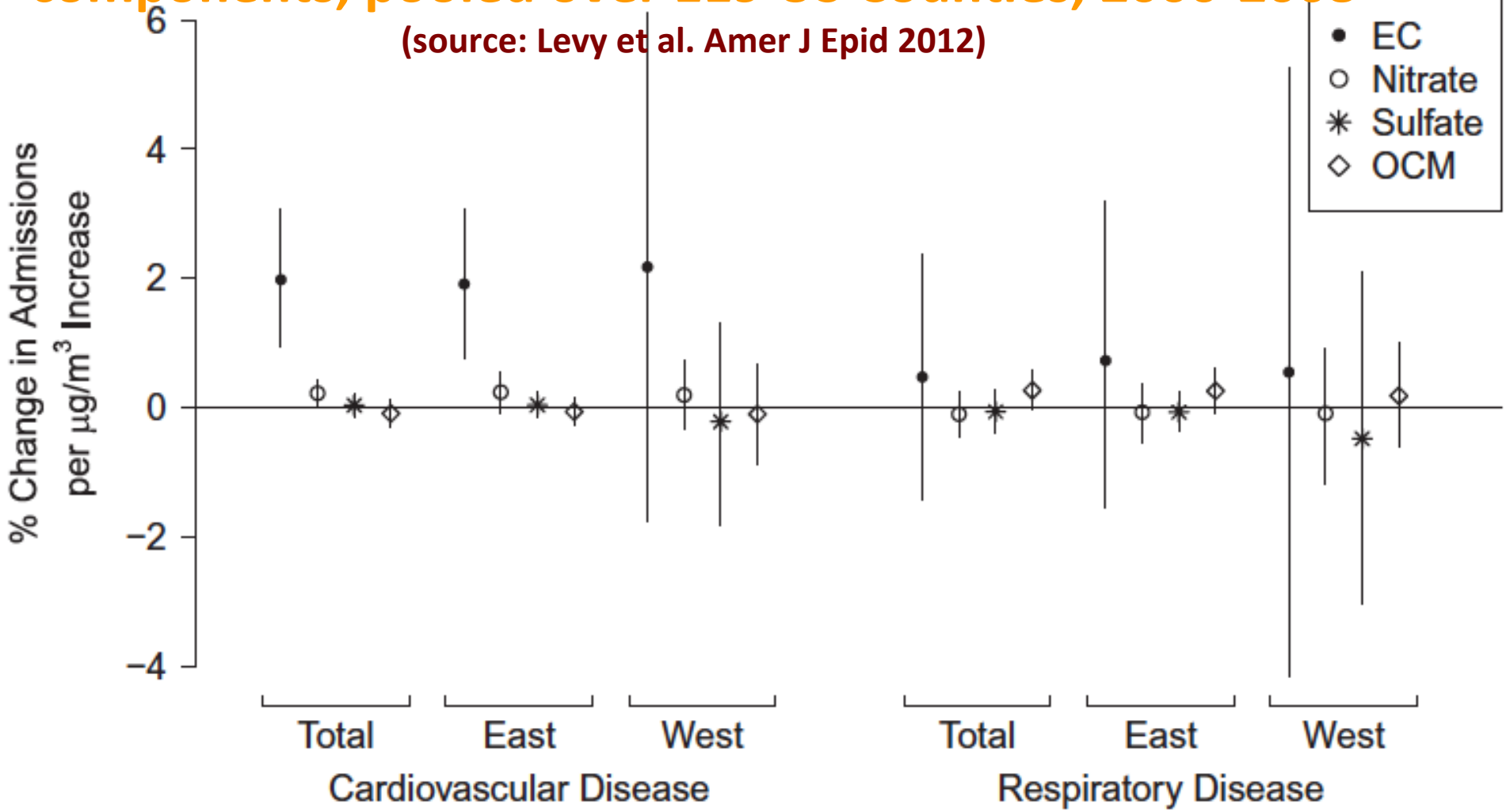
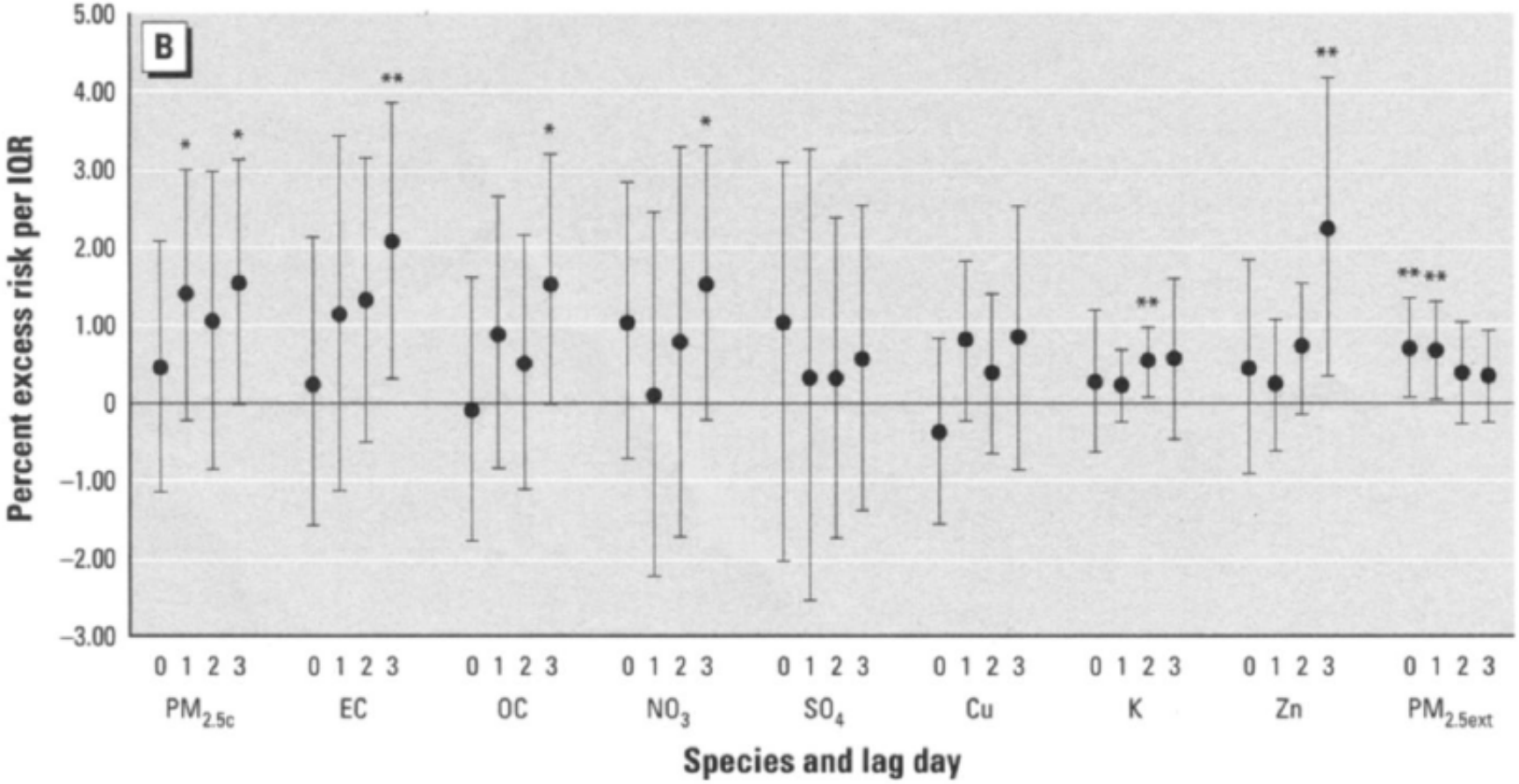


Figure 1. Percent change in hospital admissions per µg/m3 increase in concentrations of fine particulate matter constituents, by region of the United States and disease, 2000–2008. (EC, elemental carbon; OCM, organic carbon matter).

Expressed as effect per IQR, EC effects on CVD mortality were similar to $PM_{2.5}$ in California (2000-2003)



The Effects of Components of Fine Particulate Air Pollution on Mortality in California: Results from CALFINE

Bart Ostro,[1] Wen-Ying Feng,[2] Rachel Broadwin,[1] Shelley Green,[1] and Michael Lipsett[3]

Environmental Health Perspectives • VOLUME 115 | NUMBER 1 | January 2007

Mortality risks of long-term exposures to PM2.5 and EC: results from cohort studies of ambient air pollution

Table 3. RR for mortality related to long-term exposure to $PM_{2.5}$ and EC per 1 μg/m^3.

Reference	Cohort	Correlation (*R*) PM–BCP[a]	Cause	RR (95% CI) $PM_{2.5}$	RR (95% CI) EC
Filleul et al. 2005[b,c]	14,284 adults; age 25–59 years; France	0.87[d]	Natural causes[e]	1.010 (1.004, 1.016)	1.06 (1.03, 1.09)
			Cardiopulmonary	1.012 (1.002, 1.023)	1.05 (0.98, 1.11)
			Lung cancer	1.000 (0.983, 1.019)	1.03 (0.93, 1.14)
Lipfert et al. 2006	70,000 male U.S. veterans	0.54	All causes	1.006 (0.993, 1.020)	1.18 (1.05, 1.33)
Beelen et al. 2008[b]	120,852 adults; age 55–69 years; the Netherlands	0.82	Natural causes[e]	1.006 (0.997, 1.015)	1.05 (1.00, 1.10)
			Respiratory	1.007 (0.972, 1.043)	1.20 (0.99, 1.45)
			Cardiovascular	1.004 (0.990, 1.019)	1.04 (0.95, 1.12)
			Lung cancer	1.006 (0.980, 1.033)	1.03 (0.89, 1.18)
			Other	1.008 (0.996, 1.021)	1.04 (0.97, 1.11)
Smith et al. 2009	500,000 adults; age 20–87 years; USA	NA	All causes	1.006 (1.002, 1.010)	1.06 (1.01, 1.11)
			Cardiopulmonary	1.012 (1.008, 1.018)	1.11 (1.03, 1.19)
Pooled effect (random)[f]			All causes	1.007 (1.004, 1.009)	1.06 (1.04, 1.09)

NA, not available.
[a]Coefficient of the correlation (*R*) between PM and BCP. [b]RR for EC in European studies estimated from BS as 10 μg/m^3 BS = 1.1 μg/m^3. [c]RR for $PM_{2.5}$ estimated from TSP as $PM_{2.5}$ = 0.5 × TSP (Verhoeff et al. 1996; Van der Zee et al. 1998). [d]For all 24 sites, whereas RR presented for 18 sites (nontraffic). [e]*International Classification of Diseases, 9th Revision* (World Health Organization 1975), codes < 800. [f]Pooled effect when using 10 μg/m^3 BS = 1.8 μg/m^3: 1.05 (95% CI: 1.02, 1.07); when using 10 μg/m^3 BS = 0.5 μg/m^3: 1.11 (95% CI: 1.06, 1.16).

Black Carbon as an Additional Indicator of the Adverse Health Effects of Airborne Particles Compared with PM_{10} and $PM_{2.5}$

Nicole A.H. Janssen,[1] Gerard Hoek,[2] Milena Simic-Lawson,[3] Paul Fischer,[1] Leendert van Bree,[4] Harry ten Brink,[5] Menno Keuken,[6] Richard W. Atkinson,[3] H. Ross Anderson,[7] Bert Brunekreef,[2,8] and Flemming R. Cassee[1]

Environmental Health Perspectives • VOLUME 119 | NUMBER 12 | December 2011

Long-Term Exposure to Traffic-Related Air Pollution and the Risk of Coronary Heart Disease Hospitalization and Mortality

Wen Qi Gan,[1] Mieke Koehoorn,[1,2] Hugh W. Davies,[1] Paul A. Demers,[1,2] Lillian Tamburic,[3] and Michael Brauer[1]

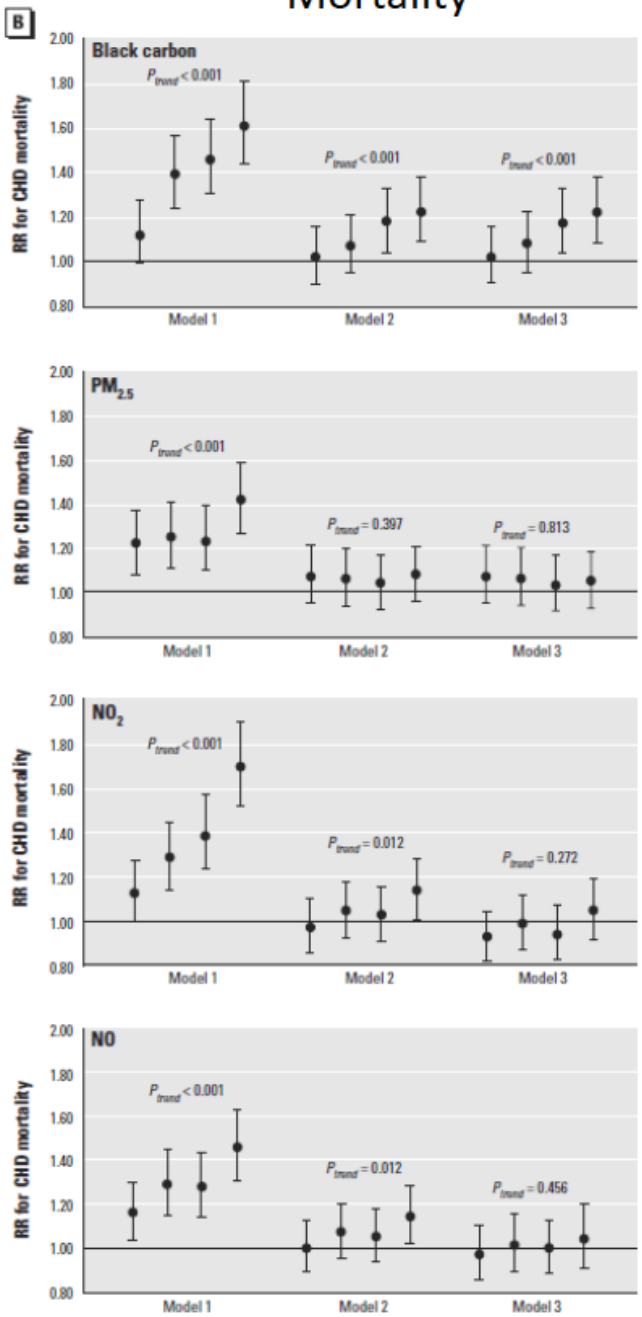
Environmental Health Perspectives • VOLUME 119 | NUMBER 4 | April 2011

Table 3. RRs (95% CIs) of CHD hospitalization and mortality for an IQR elevation in average concentrations of traffic-related air pollutants.

Model	BC (0.94×10^{-5}/m)[a]	$PM_{2.5}$ (1.58 μg/m^3)[a]	NO_2 (8.4 μg/m^3)[a]	NO (13.2 μg/m^3)[a]
Hospitalization				
Model 1: unadjusted single pollutant	1.04 (1.03–1.06)	1.03 (1.01–1.05)	1.02 (1.00–1.04)	0.99 (0.97–1.02)
Model 2: + sex, age, comorbidity, SES	1.01 (1.00–1.03)	1.00 (0.98–1.02)	0.97 (0.95–0.99)	0.96 (0.94–0.98)
Model 3: + two other pollutants[b]	1.03 (1.01–1.05)	1.02 (1.00–1.05)	0.96 (0.94–0.98)	0.95 (0.92–0.97)
Mortality				
Model 1: unadjusted single pollutant	1.14 (1.11–1.17)	1.13 (1.09–1.16)	1.19 (1.15–1.23)	1.13 (1.09–1.17)
Model 2: + sex, age, comorbidity, SES	1.06 (1.03–1.09)	1.01 (0.98–1.05)	1.04 (1.01–1.08)	1.06 (1.02–1.10)
Model 3: + two other pollutants[b]	1.06 (1.03–1.09)	1.00 (0.96–1.03)	1.03 (0.99–1.07)	1.03 (0.99–1.08)

+, additionally adjusted for covariates.
[a]IQR. [b]Additionally adjusted for $PM_{2.5}$ and NO_2 for black carbon, black carbon and NO_2 for $PM_{2.5}$, black carbon and $PM_{2.5}$ for NO_2 and NO.

Mortality



Highway proximity and black carbon from cookstoves as a risk factor for higher blood pressure in rural China

Jill Baumgartner[a,b,1], Yuanxun Zhang[c], James J. Schauer[d], Wei Huang[c], Yuqin Wang[c], and Majid Ezzati[e]

The effect of BC on SBP was almost three times greater in women living near the highway [6.2 mmHg; 95% confidence interval (CI), 3.6 to 8.9 vs. 2.6 mmHg; 95% CI, 0.1 to 5.2].

www.pnas.org/cgi/doi/10.1073/pnas.1317176111

Effects of personal exposures on systolic blood pressure in rural China. Baumgartner et al., PNAS 2014

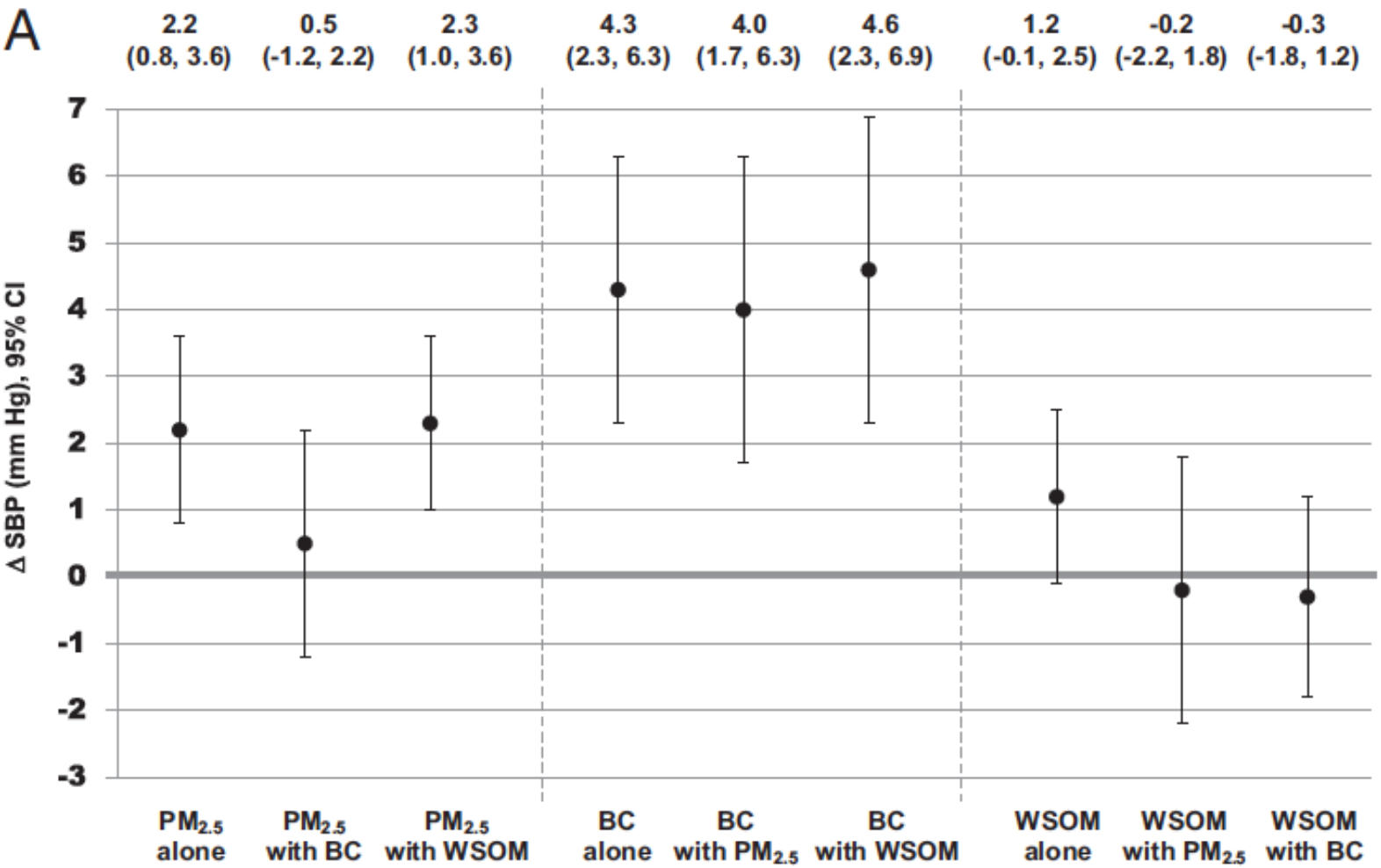


Fig. 1. Associations of personal exposure to PM mass, BC, and WSOM on (A) SBP using one- and two-pollutant mixed-effects regression models. ΔSBP represents the difference in SBP (with 95% CIs) associated with a 1-ln(μg/m3) increase in pollutant exposure.

Implications

- BC in the atmosphere appears to be one of the key, if not THE key, risk metrics for CVD impacts
- BC is a reliable indicator of freshly generated combustion aerosols, which seem to confer greater risk than secondary PM components
- The high correlation between BC and $PM_{2.5}$ means that to some extent it doesn't matter which you measure. However, the more robust results for BC in co-pollutant epidemiologic analyses argues in favor of BC
- The evidence to-date suggests that BC is a good indicator of the bundle of toxic pollutants that perpetrate adverse effects on cardiovascular health