Atmospheric Elemental Carbon Pollution and Its Regional Health Disparities in China

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I. BACKGROUND

- $PM_{2.5}$ concentration in China has significantly decreased (Zhang et al., 2019). But, a large reduction of total $PM_{2.5}$ does not mean the toxicity of the air reduces accordingly.

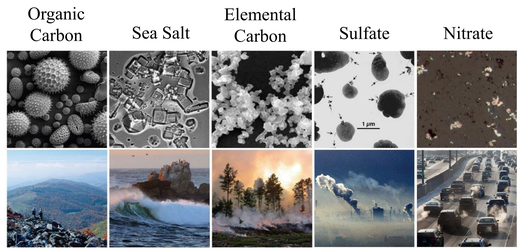

Figure 1. Major $PM_{2.5}$ constituents and sources.

- Possible elevated toxicity of elemental carbon (EC).

Table 1. Relative risk for mortality related to long-term exposure to $PM_{2.5}$ and EC per 1 μg m^{-3} (Janssen et al., 2011).

Reference	Cohort	Correlation (R) $PM–BC^{a,b}$
Filleul et al. 2005[b,c]	14,284 adults; age 25–59 years; France	0.87[d]
Lipfert et al. 2006	70,000 male U.S. veterans	0.54
Beelen et al. 2008[b]	120,852 adults; age 55–69 years; the Netherlands	0.82
Smith et al. 2009	500,000 adults; age 20–87 years; USA	NA
Pooled effect (random)[f]		

		RR (95% CI)	
Reference	Cause	$PM_{2.5}$	EC
Filleul et al. 2005[b,c]	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	All causes	1.006 (0.993, 1.020)	1.18 (1.05, 1.33)
Beelen et al. 2008[b]	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	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)

- It is needed to understand the spatiotemporal variation of long-term elemental carbon exposure in China and its health risk. However, ground monitoring network of $PM_{2.5}$ constituents does not exist in China.

II. RESEARCH OBJECTIVES

- Improve our understanding of $PM_{2.5}$ constituents and their health risks.
- Specifically, to investigate the health impact of long-term elemental carbon exposure in China.
- Therefore, we can further improve air quality to promote public health.

III. DATA AND METHOD

- Available Ground Measurements of EC + Unique MISR Aerosol Data + Machine Learning

Model output: Daily EC concentration
Study period: 2005-2018
Machine learning model: Random forest
Resolution: 10-km
Model input:

- Terra's MISR aerosol optical depth
- Ground observational records of EC
- GEOS meteorological condition
- MERRA-2 atmospheric composition
- CAMS emission inventory
- Other supporting information (i.e., land type, etc.)

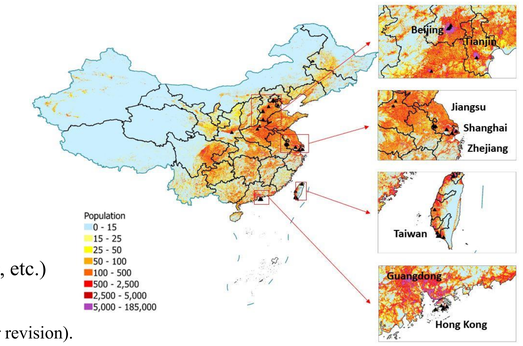

Figure 2. Map of study domain, the spatial distribution of monitoring sites, and population density (Hang et al., under revision).

IV. RESULTS

- Model performance

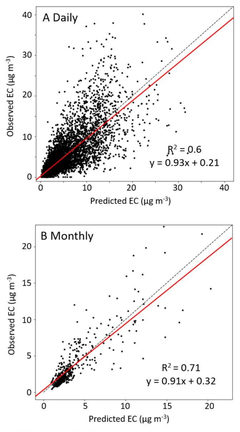

Figure 3. Linear regression between measured and out-out-bag predicted EC concentrations (Hang et al., under revision).

- Long-term spatial variations in EC

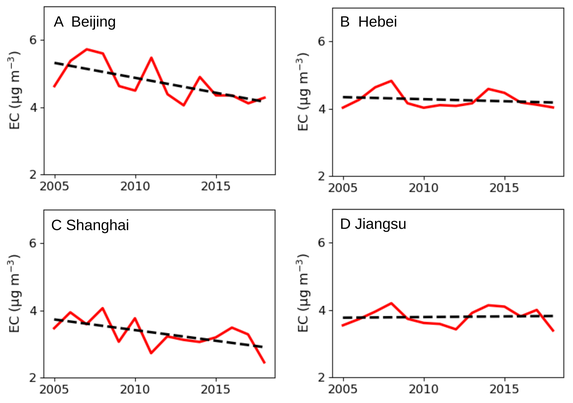

Figure 4. Annual mean population-weighted EC concentration (red line) of (A) Beijing, (B) Hebei, (C) Shanghai, and (D) Jiangsu. The dashed lines are calculated linear trends over 2005-2018 (Hang et al., under revision).

- EC concentration of first-tier cities Beijing and Shanghai decreased by 7.4% and 29.2% from 2005-2018.
- However, the EC level of their adjacent provinces Hebei and Jiangsu was relatively stable during the entire study period.

- Mortality burden attributable to long-term EC exposure

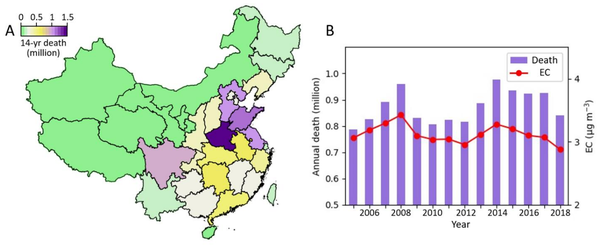

Figure 5. (A) 14-year cumulative death in each province of China from 2005-2018, (B) national mean annual EC concentration and its corresponding premature death number (Hang et al., under revision).

- The first estimate of long-term mortality burden from EC in China.
- In 2018, the national mortality burden attributable to EC was about 0.7 million.
- EC regulations in China were effective in first-tier cities, but need more effort to control emissions from coal-power plants, industrial facilities, and on-road vehicles in other regions.

V. SUMMARY

- The health burden of long-term EC exposure in first-tier cities was much lower than in their surrounding provinces.
- Although air quality in China has been significantly improved, reducing health inequity among different regions may need more attention.

VI. FUTURE WORK

- How about the organic carbon pollution? And, the OC/EC ration for pollution source investigation?

$$OC_{i,j} = f_m(\boldsymbol{AOD}_{i,j}, \boldsymbol{X}_{i,j}, \boldsymbol{Z}_{i,j})$$

$$\hat{f}_{SL}(\cdot) = \hat{f}_{NNLS}(\widehat{OC}_{m,i,j}) = \hat{a}_1\widehat{OC}_{RF,i,j} + \hat{a}_1\widehat{OC}_{XGB,i,j} + \hat{a}_1\widehat{OC}_{LGB,i,j}$$

- $OC_{i,j}$: ground observed OC concentrations at grid cell i on day j;
- $\boldsymbol{AOD}_{i,j}$: MISR fractional AODs;
- $\boldsymbol{X}_{i,j}$: spatiotemporal covariates;
- $\boldsymbol{Z}_i$: spatial covariates;
- m = 1,2,3 represents three base-learners of RF, XGB, and LGB;
- $\hat{f}_{SL}(\cdot)$ represents the OC predictions using SL that is based on non-negative least square model, also denoted as $\hat{f}_{NNLS}(\widehat{OC}_{m,i,j})$.

Figure 6. A super-learner based organic carbon prediction model (Hang and Pu et al., in submission).

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