

Supplemental Material for

**PM<sub>2.5</sub> and its components and respiratory disease healthcare encounters – unanticipated increased exposure-response relationships in recent years after environmental policies**

Shao Lin, MD, PhD,<sup>1,\*</sup> Yukang Xue, MS,<sup>2,\*</sup> Sathvik Thandra, BS,<sup>3</sup> Quan Qi, MS,<sup>4</sup> Philip K. Hopke, PhD,<sup>5,6</sup> Sally W. Thurston, PhD,<sup>7,8</sup> Daniel P. Croft MD, MPH,<sup>9</sup> Mark J. Utell, MD,<sup>7,9</sup> David Q. Rich, ScD<sup>5,7,9</sup>

\* These two authors are designated as co-first authors.

1. Department of Environmental Health Sciences & Department of Epidemiology/Biostatistics, University at Albany, the State University of New York, Albany, New York
2. Department of Educational and Counseling Psychology, University at Albany, the State University of New York, Albany, New York
3. Department of Mathematics and Statistics, University at Albany, State University of New York, Albany, New York
4. Department of Economics, University at Albany, the State University of New York, Albany, New York
5. Department of Public Health Sciences, University of Rochester Medical Center, Rochester, New York
6. Institute for a Sustainable Environment, Clarkson University, Potsdam, New York
7. Department of Environmental Medicine, University of Rochester Medical Center, Rochester, New York
8. Department of Biostatistics and Computational Biology, University of Rochester Medical Center, Rochester, New York
9. Department of Medicine, Division of Pulmonary and Critical Care, University of Rochester Medical Center, Rochester, New York.

**Corresponding author:**

Dr. David Rich

Department of Public Health Sciences,  
University of Rochester Medical Center  
265 Crittenden Blvd, CU 420644  
Rochester, NY 14642,  
USA.

E-mail address: david\_rich@urmc.rochester.edu

**Supplement Table S1. Demographic characteristics of patients with asthma and COPD hospitalizations and ED visits in 2014-2016 and 2017-2019, NYS**

Sources / Demographic variables		2014-2016		2017-2019	
		(N = 707804)		(N = 647632)	
		<i>n</i>	%	<i>n</i>	%
<b>GENDER</b>					
	Male	326,626	46	297,832	46
	Female	381,176	54	349,788	54
<b>AGE</b>					
	0-5	92,834	13	73,386	11
	6-17	102,791	15	86,004	13
	18-64	372,241	53	342,944	53
	65+	139,938	20	145,298	22
<b>RACE</b>					
	White	252,323	36	236,909	37
	Black	251,230	35	221,442	34
	Native American / Alaskan	2,089	0	1,798	0
	Asian	11,401	2	15,129	2
	Native Hawaiian	524	0	628	0
<b>ETHNICITY</b>					
	Hispanic	145,937	21	134,996	21
	Non-Hispanic	561,867	79	512,636	79
<b>YEAR</b>					
	2014	240,044	34	N/A	N/A
	2015	238,359	34	N/A	N/A
	2016	229,401	32	N/A	N/A
	2017	N/A	N/A	219,531	34
	2018	N/A	N/A	202,323	31
	2019	N/A	N/A	225,778	35

**Supplement Table S2. Distribution of PM<sub>2.5</sub>, POC, and SOC concentrations (µg/m<sup>3</sup>), by time period, during case periods and control periods, NYS.**

Source		Case Periods						Control Periods					
	Time Period	5 <sup>th</sup> %tile	25 <sup>th</sup> %tile	50 <sup>th</sup> %tile	75 <sup>th</sup> %tile	95 <sup>th</sup> %tile	Max.	5 <sup>th</sup> %tile	25 <sup>th</sup> %tile	50 <sup>th</sup> %tile	75 <sup>th</sup> %tile	95 <sup>th</sup> %tile	Max.
PM <sub>2.5</sub>	Overall	2.3	4.5	6.846	10.09	16.41	45.4	2.3	4.5	6.8	10	16.3	45.4
	2014-2016	2.6	4.8	7.3	10.8	17.1	45.4	2.6	4.8	7.3	10.7	17	45.4
	2017-2019	1.9	4.04	6.23	9.12	14.9	33.07	1.88	4.03	6.21	9.08	14.79	33.07
SOC	Overall	0.038	0.430	0.779	1.333	2.593	11.63	0.033	0.426	0.777	1.331	2.553	11.631
	2014-2016	0.036	0.442	0.862	1.444	2.700	11.63	0.038	0.444	0.858	1.421	2.695	11.631
	2017-2019	0.040	0.419	0.733	1.203	2.425	4.907	0.023	0.414	0.729	1.205	2.425	4.907
POC	Overall	0.150	0.398	0.727	1.177	1.777	4.214	0.148	0.393	0.722	1.171	1.767	4.214
	2014-2016	0.141	0.313	0.515	1.009	1.662	3.743	0.141	0.309	0.506	0.999	1.671	3.743
	2017-2019	0.183	0.589	0.987	1.307	1.898	4.214	0.176	0.585	0.993	1.304	1.888	4.214

**Supplement Table S3. The number of cases for COPD admissions and ED visits associated with each IQR<sup>@</sup> increase in SOC and POC concentrations in the previous 7 days, by period.**

Admission / ED visits	IQR	SOC Cases		IQR	POC Cases	
		2014-2016	2017-2019		2014-2016	2017-2019
<b><u>Admissions</u></b>						
<i>Asthma</i>						
0	0.82	19,269	11,496	0.55	19,269	11,496
0-3	0.61	17,689	10,254	0.43	17,689	10,254
0-6	0.67	18,811	11,066	0.45	18,811	11,066
<b><i>COPD</i></b>						
0	0.81	14,111	14,294	0.55	14,111	14,294
0-3	0.70	12,346	11,956	0.38	12,346	11,956
0-6	0.65	13,740	13,845	0.47	13,740	13,845
<b><u>ED visits</u></b>						
<i>Asthma</i>						
0	0.78	103,244	78,672	0.54	103,244	78,672
0-3	0.63	4,578	70,326	0.41	94,578	70,326
0-6	0.60	100,864	75,782	0.46	100,864	75,782
<b><i>COPD</i></b>						
0	0.81	9,867	11,121	0.54	9,867	11,121
0-3	0.74	8,175	8,726	0.38	8,175	8,726
0-6	0.67	9,580	10,767	0.47	9,580	10,767

<sup>@</sup> IQR: Interquartile Range ( $\mu\text{g}/\text{m}^3$ ).

**Supplement Table S4. Excess rate of asthma and COPD hospitalizations associated with interquartile range (IQR) increases in PM<sub>2.5</sub>, SOC, POC concentrations on lag days 0-6, stratified by demographic variables in NYS, 2014-2019.**

Pollutants/Demographics		Asthma (N = 139,956)		COPD (N = 207,166)	
		IQR <sup>@</sup> (µg/m <sup>3</sup> )	Excess Rate	IQR <sup>@</sup> (µg/m <sup>3</sup> )	Excess Rate
<b>PM<sub>2.5</sub></b>					
GENDER	Male	3.15	3.3 (1.7, 4.9)	3.14	3.4 (1.8, 5.0)
	Female	3.40	1.2 (-0.2, 2.7)	3.09	2.8 (1.4, 4.2)
AGE	0-5	2.81	1.6 (-0.3, 3.4)	7.07	-7.9 (-59.3, 108.5)
	6-17	2.92	3.1 (0.8, 5.4)	2.37	-13.8 (-40.1, 24.1)
	18-64	3.54	1.7 (-0.1, 3.5)	3.11	4.2 (2.4, 6.0)
	65+	3.74	2.0 (-0.8, 4.9)	3.11	2.4 (1.1, 3.8)
RACE	White	3.37	1.0 (-1.5, 3.5)	3.13	2.2 (0.6, 3.7)
	Black	3.19	3.5 (1.9, 5.2)	2.97	4.4 (2.5, 6.4)
	Asian	3.00	2.6 (-2.6, 8.2)	3.35	5.0 (-2.0, 12.5)
ETHNICITY	Hispanic	3.07	1.6 (-0.2, 3.4)	2.98	1.6 (-1.0, 4.3)
	Non-Hispanic	3.29	2.3 (1.0, 3.6)	3.11	3.3 (2.1, 4.4)
Urbanicity	NYC <sup>#</sup>	3.28	2.2 (1.1, 3.3)	3.11	3.5 (2.3, 4.7)
	Upstate	3.28	1.0 (-2.4, 4.6)	3.11	1.6 (-0.7, 3.9)
<b>POC</b>					
GENDER	Male	0.46	6.1 (0.1, 12.4)	0.45	-0.2 (-5.2, 5.0)
	Female	0.44	0.5 (-4.1, 5.3)	0.46	-2.7 (-7.0, 1.9)
AGE	0-5	0.49	10.4 (2.6, 18.9)	/	/
	6-17	0.57	15.8 (4.7, 28.1)	/	/
	18-64	0.44	-4.6 (-9.5, 0.5)	0.48	1.1 (-4.1, 6.7)
	65+	0.37	0.5 (-6.1, 7.5)	0.47	-3.9 (-7.8, 0.2)
RACE	White	0.45	-4.8 (-11.6, 2.6)	0.47	0.4 (-4.1, 5.0)
	Black	0.45	6.0 (0.3, 12.0)	0.49	-3.0 (-9.0, 3.5)
	Asian	0.36	-4.1 (-14.3, 7.3)	0.26	-3.7 (-12.4, 5.9)
ETHNICITY	Hispanic	0.49	-0.5 (-7.0, 6.3)	0.52	-6.6 (-15.3, 3.1)
	Non-Hispanic	0.45	3.8 (-0.3, 8.1)	0.47	-1.3 (-4.7, 2.2)
Urbanicity	NYC <sup>#</sup>	0.46	2.7 (-1.0, 6.5)	0.47	-3.5 (-7.0, 0.3)
	Upstate	0.46	0.9 (-8.7, 11.6)	0.47	2.9 (-3.6, 9.8)
<b>SOC</b>					
GENDER	Male	0.66	-2.0 (-6.8, 3.0)	0.67	3.2 (-1.7, 8.4)
	Female	0.68	-2.5 (-6.5, 1.7)	0.65	5.9 (1.4, 10.5)
AGE	0-5	0.64	-2.4 (-8.2, 3.8)	/	/
	6-17	0.69	4.5 (-3.2, 12.9)	/	/
	18-64	0.69	-4.2 (-8.7, 0.5)	0.64	4.2 (-0.7, 9.4)
	65+	0.61	-0.8 (-7.0, 5.8)	0.66	4.1 (0.1, 8.2)
RACE	White	0.66	-5.3 (-11.6, 1.5)	0.65	3.5 (-0.9, 8.1)
	Black	0.67	-1.0 (-5.5, 3.7)	0.70	7.1 (1.0, 13.7)
	Asian	0.41	8.1 (-2.7, 20.1)	0.18	3.4 (-1.4, 8.5)
ETHNICITY	Hispanic	0.52	-0.2 (-4.5, 4.2)	0.41	0.9 (-4.1, 6.1)
	Non-Hispanic	0.69	-2.0 (-5.6, 1.7)	0.67	4.7 (1.3, 8.2)
Urbanicity	NYC <sup>#</sup>	0.67	-0.9 (-4.0, 2.4)	0.66	3.9 (0.4, 7.5)
	Upstate	0.67	-10.6 (-19.5, -0.7)	0.65	2.7 (-4.1, 10.0)

<sup>@</sup> IQR: Interquartile Range.

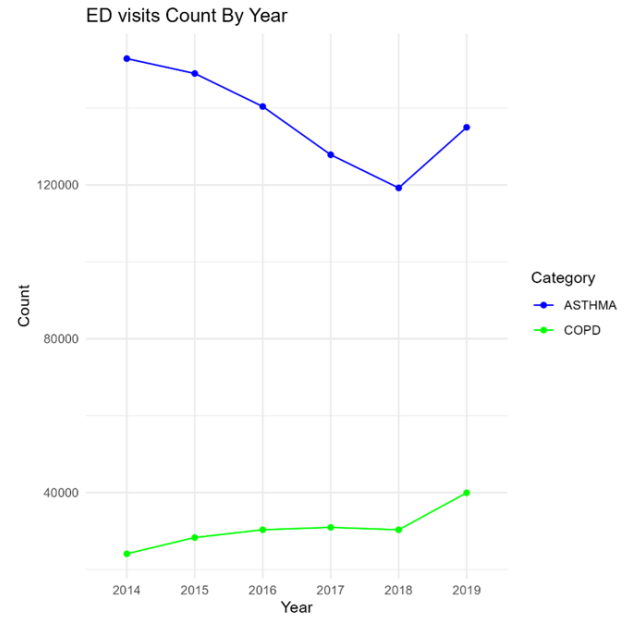
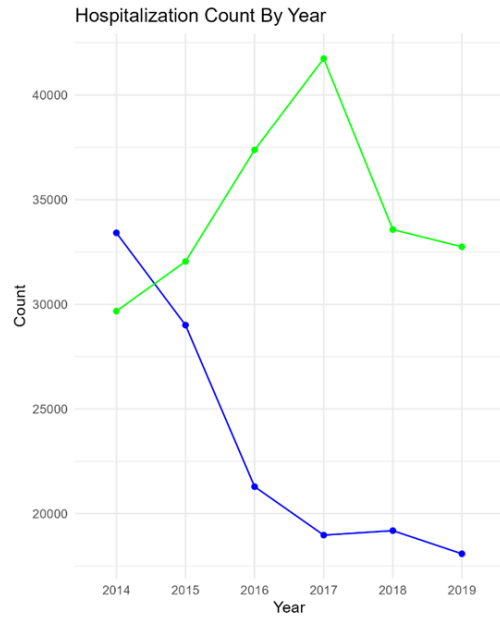
<sup>#</sup> NYC: New York City

**Supplement Table S5. Excess rate of asthma and COPD ED visits associated with each interquartile range (IQR) increase in PM<sub>2.5</sub>, SOC, POC concentrations on lag days 0-6, stratified by demographic variables in NYS, 2014-2019.**

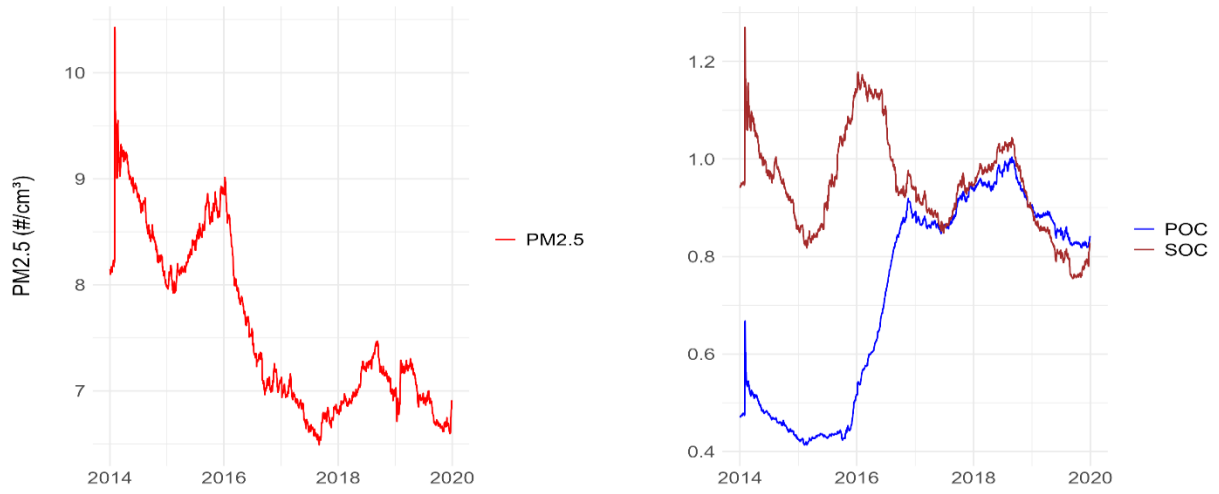
Pollutants/Demographics		Asthma (N = 824,225)		COPD (N = 184,089)	
		IQR <sup>@</sup> (µg/m <sup>3</sup> )	Excess Rate	IQR <sup>@</sup> (µg/m <sup>3</sup> )	Excess Rate
<b>PM<sub>2.5</sub></b>					
GENDER	Male	3.04	3.1 (2.5, 3.7)	3.13	2.6 (0.9, 4.4)
	Female	3.07	1.8 (1.3, 2.4)	3.01	2.2 (0.6, 3.8)
AGE	0-5	3.11	2.7 (1.7, 3.6)	3.91	5.3 (-24.8, 47.6)
	6-17	3.00	4.4 (3.5, 5.3)	2.70	17.3 (-11.0, 54.7)
	18-64	3.05	1.5 (0.9, 2.0)	3.08	1.9 (0.3, 3.4)
	65+	3.06	3.4 (1.7, 5.2)	3.05	3.1 (1.2, 4.9)
RACE	White	3.07	1.5 (0.5, 2.6)	3.11	1.6 (-0.2, 3.5)
	Black	3.04	2.4 (1.8, 3.0)	2.93	3.0 (1.1, 4.9)
	Asian	3.02	3.1 (0.4, 5.9)	3.38	-4.0 (-14.3, 7.7)
ETHNICITY	Hispanic	3.08	2.8 (2.1, 3.6)	3.10	3.8 (0.7, 7.1)
	Non-Hispanic	3.05	2.3 (1.8, 2.7)	3.05	2.1 (0.8, 3.4)
Urbanicity	NYC <sup>#</sup>	3.05	2.6 (2.2, 3.0)	3.06	3.7 (2.2, 5.1)
	Upstate	3.05	0.4 (-0.9, 1.8)	3.06	-0.6 (-2.7, 1.5)
<b>POC</b>					
GENDER	Male	0.44	3.1 (0.7, 5.5)	0.43	-0.1 (-6.4, 6.6)
	Female	0.43	1.2 (-1.0, 3.5)	0.43	-1.3 (-7.1, 5.0)
AGE	0-5	0.45	5.5 (2.2, 9.0)	/	/
	6-17	0.45	5.9 (2.8, 9.1)	/	/
	18-64	0.47	-0.3 (-2.2, 1.6)	0.47	0.5 (-4.5, 5.9)
	65+	0.50	0.3 (-6.2, 7.3)	0.49	-0.0 (-5.8, 6.1)
RACE	White	0.46	2.8 (-0.8, 6.5)	0.48	-0.6 (-6.1, 5.2)
	Black	0.46	1.3 (-0.8, 3.4)	0.51	1.4 (-5.4, 8.7)
	Asian	0.44	-1.1 (-8.0, 6.3)	/	/
ETHNICITY	Hispanic	0.48	4.2 (1.4, 7.1)	0.44	-0.8 (-10.1, 9.4)
	Non-Hispanic	0.46	1.3 (-0.3, 3.0)	0.48	0.5 (-3.6, 4.8)
Urbanicity	NYC <sup>#</sup>	0.46	2.1 (0.5, 3.6)	0.48	0.8 (-4.0, 5.9)
	Upstate	0.46	1.3 (-2.7, 5.4)	0.48	-0.8 (-7.0, 5.8)
<b>SOC</b>					
GENDER	Male	0.62	0.8 (-1.1, 2.7)	0.71	0.5 (-5.6, 7.0)
	Female	0.61	-1.1 (-2.8, 0.7)	0.75	1.4 (-4.8, 8.0)
AGE	0-5	0.58	0.1 (-2.5, 2.7)	/	/
	6-17	0.59	-2.7 (-5.0, -0.3)	/	/
	18-64	0.59	0.1 (-1.3, 1.5)	0.67	3.3 (-1.3, 8.1)
	65+	0.63	-0.8 (-5.5, 4.3)	0.65	-0.6 (-5.6, 4.6)
RACE	White	0.58	-0.2 (-3.1, 2.7)	0.69	3.6 (-1.9, 9.3)
	Black	0.61	-0.4 (-2.0, 1.2)	0.62	2.8 (-2.4, 8.3)
	Asian	0.66	9.7 (0.7, 19.5)	/	/
ETHNICITY	Hispanic	0.57	-2.0 (-3.9, -0.0)	0.59	-0.7 (-8.6, 7.9)
	Non-Hispanic	0.61	0.1 (-1.2, 1.5)	0.68	2.3 (-1.5, 6.2)
Urbanicity	NYC <sup>#</sup>	0.61	-0.0 (-1.2, 1.1)	0.68	0.4 (-3.7, 4.7)
	Upstate	0.61	-3.6 (-7.0, -0.1)	0.68	4.0 (-2.7, 11.3)

<sup>@</sup> IQR: Interquartile Range.

<sup>#</sup> NYC: New York City



**Supplement Figure S1. Temporal trend of total counts of hospitalizations and emergency department visits for both asthma and COPD in NYS, 2014-2019.**



**Supplement Figure S2. Annual temporal trends in PM<sub>2.5</sub>, POC and SOC concentrations by year from 2014-2020, NYS.**