Research Report 238

Ambient Air Pollution and COVID-19 in California

Michael Kleeman et al.

Appendix B. Supplemental Information for Chapter 4: Risks of Species-Specific Air Pollution for COVID-19 Incidence and Mortality in Los Angeles

---

Appendix B was reviewed by the HEI Review Committee and has been lightly edited for spelling, grammar, punctuation, and cross-references to the main report.

Correspondence may be addressed to Dr. Michael Kleeman, University of California, Davis, Department of Civil and Environmental Engineering, 1 Shields Avenue, Davis, CA 95616; email: *mjkleeman@ucdavis.edu*.

Although this document was produced with partial funding by the United States Environmental Protection Agency under Assistance Award CR–83998101 to the Health Effects Institute, it has not been subjected to the Agency's peer and administrative review and may not necessarily reflect the views of the Agency; thus, no official endorsement by it should be inferred. It also has not been reviewed by private-party institutions, including those that support the Health Effects Institute, and may not reflect the views or policies of these parties; thus, no endorsement by them should be inferred.

CONTENTS

1. IRRs of Air Pollutants in One-Pollutant Model

IRRs and corresponding 95% CIs for each pollutant in relation to COVID-19 incidence and mortality, derived from one-pollutant models (Table B1). Confounders, including sex, age, race, mean median income, and mean homeowner occupancy rate, as well as mean prevalences of current smoking status and obesity, were adjusted for in the models.

Table B1. One-Pollutant Negative Binomial Model

Outcome	IRR	95% CI	Pollutant
case	1.156	(1.094, 1.223)	$PM_{0.1}$ mass
case	1.028	(0.988, 1.07)	$PM_{2.5}$ nitrate
case	1.022	(0.981, 1.064)	$PM_{2.5}$ (CTM)
case	1.111	(1.048, 1.177)	$PM_{2.5}$ (LUR)
case	1.08	(1.022, 1.141)	$PM_{2.5}$ EC
case	1.085	(1.023, 1.15)	$PM_{2.5}$ tracer 1
case	1.121	(1.065, 1.18)	ozone
case	1.053	(0.993, 1.116)	NO_2 (CTM)
case	1.051	(1.004, 1.1)	NO_2 (LUR)
death	1.145	(1.053, 1.245)	$PM_{0.1}$ mass
death	1.068	(1.003, 1.137)	$PM_{2.5}$ nitrate
death	1.028	(0.957, 1.104)	$PM_{2.5}$ (CTM)
death	1.173	(1.067, 1.289)	$PM_{2.5}$ (LUR)
death	1.137	(1.04, 1.244)	$PM_{2.5}$ EC
death	1.144	(1.043, 1.255)	$PM_{2.5}$ tracer 1
death	1.268	(1.171, 1.372)	ozone
death	1.087	(0.986, 1.198)	NO_2 (CTM)
death	1.016	(0.937, 1.1)	NO_2 (LUR)

2. Coefficients from Full One-Pollutant Models

In Table B2, each row represents the estimated coefficients from a one-pollutant negative binomial model. This set of full models incorporates predictor variables, including one-pollutant concentration ("pollutant"), sex ("male"), age ("age70up"), race ("nonwhite"), mean homeowner occupancy rate ("occpncy"), mean median income ("mednncm"), and mean prevalences of current smoking status ("smoking") and obesity ("obesity").

Table B2. Coefficients of *Each Variable* from *One-Pollutant Negative Binomial Models* for COVID-19 (a) *Cases* and (b) *Deaths*

(a) Cases								
	pollutant	nonwhite	age70up	male	occpncy	mednncm	smoking	obesity
$PM_{0.1}$ mass	1.45e-01	7.27e-01	1.13	-1.20	-9.75e-06	-4.80e-06	-7.17e-05	4.55e-05
	***	***	*	**		***		**
$PM_{2.5}$ nitrate	2.73e-02	9.87e-01	1.19	-9.30e-01	-1.30e-05	-5.09e-06	-6.31e-05	4.36e-05
		***	*	*		***		**
$PM_{2.5}$ (CTM)	2.17e-02	9.67e-01	1.17	-1.02	-1.19e-05	-5.15e-06	-6.44e-05	4.38e-05
		***	*	*		***		*
$PM_{2.5}$ (LUR)	1.05e-01	8.04e-01	1.32	-1.03	-1.026e-05	-4.32e-06	-5.13e-05	3.86e-05
	***	***	**	*		***		*
$PM_{2.5}$ EC	7.69e-02	8.70e-01	1.38	-1.10	-5.83e-06	-4.93e-06	-4.86e-05	3.55e-05
	**	***	**	*		***		*
$PM_{2.5}$ tracer 1	8.14e-02	8.88e-01	1.42	-1.18	-6.40e-06	-4.89e-06	-5.20e-05	3.70e-05
	**	***	**	**		***		*
ozone	1.14e-01	9.51e-01	9.92e-01	-9.72e-01	-2.72e-05	-5.27e-06	-1.06e-04	6.57e-05
	***	***	*	*	**	***	**	***
NO_2 (CTM)	5.15e-02	9.29e-01	1.26	-1.09	-9.61e-06	-4.98e-06	-6.22e-05	4.23e-05
		***	*	*		***		*
NO_2 (LUR)	4.94e-02	9.48e-01	1.20	-9.64e-01	-9.11e-06	-4.86e-06	-5.38e-05	3.85e-05
	*	***	*	*		***		*

$^{*}P < 0.05$. $^{**}P < 0.01$. $^{***}P < 0.001$.

Continued next page

(b) Deaths

	pollutant	nonwhite	age70 up	male	occpncy	mednncm	smoking	obesity
$PM_{0.1}$ mass	1.35e-01 **	5.66e-01 ***	-1.12 ***	-2.87e-02	-1.61e-05	-8.81e-06 ***	-6.03e-05	2.56e-05
$PM_{2.5}$ nitrate	6.57e-02 *	5.86e-01 ***	-1.13 ***	-5.63e-02	-1.51e-05	-9.92e-06 ***	-3.96e-05	1.85e-05
$PM_{2.5}$ (CTM)	2.79e-02	6.18e-01 ***	-1.16 ***	-1.23e-02	-1.69e-05	-9.89e-06 ***	-5.30e-05	2.38e-05
$PM_{2.5}$ (LUR)	1.60e-01 ***	4.62e-01 ***	-1.08 ***	-4.56e-02	-1.38e-05	-8.56e-06 ***	-3.24e-05	1.56e-05
$PM_{2.5}$ EC	1.29e-01 **	4.96e-01 ***	-1.08 ***	-5.92e-02	-6.47e-06	-9.43e-06 ***	-2.92e-05	1.21e-05
$PM_{2.5}$ tracer 1	1.35e-01 **	5.27e-01 ***	-1.08 ***	-5.70e-02	-7.15e-06	-9.41e-06 ***	-3.43e-05	1.44e-05
ozone	2.37e-01 ***	8.60e-01 ***	-1.21 ***	-3.00e-02	-4.36e-05 ***	-8.48e-06 ***	-1.05e-04 *	5.16e-05 *
NO_2 (CTM)	8.33e-02	5.57e-01 ***	-1.12 ***	-2.52e-02	-1.25e-05	-9.62e-06 ***	-4.90e-05	2.15e-05
NO_2 (LUR)	1.55e-02	6.38e-01 ***	-1.17 ***	-5.78e-04	-1.89e-05	-9.95e-06 ***	-5.82e-05	2.60e-05

$^{*}P < 0.05$. $^{**}P < 0.01$. $^{***}P < 0.001$.

3. Two-Pollutant Model

IRRs and corresponding 95% CIs for COVID-19 incidence and mortality, based on two-pollutant models between **(a)** NO_2 (CTM) and ozone, **(b)** NO_2 (LUR) and ozone, **(c)** $PM_{2.5}$ (CTM) and ozone, **(d)** $PM_{2.5}$ (LUR) and ozone, **(e)** NO_2 (CTM) and $PM_{2.5}$ (CTM), and **(f)** NO_2 (LUR) and $PM_{2.5}$ (LUR) are presented below.

Table B3. Comparison Between IRRs from One- and Two-Pollutant Models

(a) NO_2 (CTM) and ozone				
Outcome	IRR	95% CI	Pollutant	Model
case	1.053	(0.993, 1.116)	NO_2 (CTM)	One-Pollutant
case	1.173	(1.101, 1.25)	NO_2 (CTM) controlled for ozone	Two-Pollutant
case	1.121	(1.065, 1.18)	ozone	One-Pollutant
case	1.207	(1.14, 1.278)	ozone controlled for NO_2 (CTM)	Two-Pollutant
	1.416		NO_2 (CTM)× ozone	
death	1.087	(0.986, 1.198)	NO_2 (CTM)	One-Pollutant
death	1.235	(1.121, 1.36)	NO_2 (CTM) controlled for ozone	Two-Pollutant
death	1.268	(1.171, 1.372)	ozone	One-Pollutant
death	1.35	(1.242, 1.467)	ozone controlled for NO_2 (CTM)	Two-Pollutant
	1.667		NO_2 (CTM) × ozone	
(b) NO_2 (LUR) and ozone				
Outcome	IRR	95% CI	Pollutant	Model
case	1.051	(1.004, 1.1)	NO_2 (LUR)	One-Pollutant
case	1.209	(1.147, 1.275)	NO_2 (LUR) controlled for ozone	Two-Pollutant
case	1.121	(1.065, 1.18)	ozone	One-Pollutant
case	1.293	(1.217, 1.375)	ozone controlled for NO_2 (LUR)	Two-Pollutant
	1.563		NO_2 (LUR) × ozone	
death	1.016	(0.937, 1.1)	NO_2 (LUR)	One-Pollutant
death	1.226	(1.123, 1.337)	NO_2 (LUR) controlled for ozone	Two-Pollutant
death	1.268	(1.171, 1.372)	ozone	One-Pollutant
death	1.421	(1.297, 1.558)	ozone controlled for NO_2 (LUR)	Two-Pollutant
	1.742		NO_2 (LUR) × ozone	
(c) $PM_{2.5}$ (CTM) and ozone				
Outcome	IRR	95% CI	Pollutant	Model
case	1.022	(0.981, 1.064)	$PM_{2.5}$ (CTM)	One-Pollutant
case	1.115	(1.064, 1.168)	$PM_{2.5}$ (CTM) controlled for ozone	Two-Pollutant
case	1.121	(1.065, 1.18)	ozone	One-Pollutant
case	1.218	(1.146, 1.294)	ozone controlled for $PM_{2.5}$ (CTM)	Two-Pollutant
	1.358		$PM_{2.5}$ (CTM) × ozone	
death	1.028	(0.957, 1.104)	$PM_{2.5}$ (CTM)	One-Pollutant

death	1.163	(1.08, 1.253)	$PM_{2.5}$ (CTM) controlled for ozone	Two-Pollutant
death	1.268	(1.171, 1.372)	ozone	One-Pollutant
death	1.371	(1.257, 1.496)	ozone controlled for $PM_{2.5}$ (CTM)	Two-Pollutant
	1.594		$PM_{2.5}$ (CTM) × ozone	

(d) $PM_{2.5}$ (LUR) and ozone

Outcome	IRR	95% CI	Pollutant	Model
case	1.111	(1.048, 1.177)	$PM_{2.5}$ (LUR)	One-Pollutant
case	1.165	(1.1, 1.233)	$PM_{2.5}$ (LUR) controlled for ozone	Two-Pollutant
case	1.121	(1.065, 1.18)	ozone	One-Pollutant
case	1.166	(1.108, 1.226)	ozone controlled for $PM_{2.5}$ (LUR)	Two-Pollutant
	1.358		$PM_{2.5}$ (LUR)*ozone	
death	1.173	(1.067, 1.289)	$PM_{2.5}$ (LUR)	One-Pollutant
death	1.197	(1.095, 1.308)	$PM_{2.5}$ (LUR) controlled for ozone	Two-Pollutant
death	1.268	(1.171, 1.372)	ozone	One-Pollutant
death	1.279	(1.183, 1.382)	ozone controlled for $PM_{2.5}$ (LUR)	Two-Pollutant
	1.531		$PM_{2.5}$ (LUR)*ozone	

(e) NO_2 (CTM) and $PM_{2.5}$ (CTM)

Outcome	IRR	95% CI	Pollutant	Model
case	1.053	(0.993, 1.116)	NO_2 (CTM)	One-Pollutant
case	1.13	(0.985, 1.297)	NO_2 (CTM) controlled for $PM_{2.5}$ (CTM)	Two-Pollutant
case	1.022	(0.981, 1.064)	PM2.5 (CTM)	One-Pollutant
case	0.947	(0.862, 1.041)	PM2.5 (CTM) controlled for NO_2 (CTM)	Two-Pollutant
	1.07		NO_2 (CTM)* $PM_{2.5}$ (CTM)	
death	1.087	(0.986, 1.198)	NO_2 (CTM)	One-Pollutant
death	1.211	(1, 1.468)	NO_2 (CTM) controlled for $PM_{2.5}$ (CTM)	Two-Pollutant
death	1.028	(0.957, 1.104)	$PM_{2.5}$ (CTM)	One-Pollutant
death	0.911	(0.792, 1.048)	$PM_{2.5}$ (CTM) controlled for NO_2 (CTM)	Two-Pollutant
	1.103		NO_2 (CTM)*$PM_{2.5}$ (CTM)	

(f) NO_2 (LUR) and $PM_{2.5}$ (LUR)

Outcome	IRR	95% CI	Pollutant	Model
case	1.051	(1.004, 1.1)	NO_2 (LUR)	One-Pollutant
case	0.962	(0.895, 1.034)	NO_2 (LUR) controlled for $PM_{2.5}$ (LUR)	Two-Pollutant
case	1.111	(1.048, 1.177)	$PM_{2.5}$ (LUR)	One-Pollutant
case	1.155	(1.052, 1.268)	$PM_{2.5}$ (LUR) controlled for NO_2 (LUR)	Two-Pollutant
	1.111		NO_2 (LUR)*$PM_{2.5}$ (LUR)	
death	1.016	(0.937, 1.1)	NO_2 (LUR)	One-Pollutant
death	0.865	(0.777, 0.962)	NO_2 (LUR) controlled for $PM_{2.5}$ (LUR)	Two-Pollutant

death	1.173	(1.067, 1.289)	$PM_{2.5}$ (LUR)	One-Pollutant
death	1.321	(1.162, 1.501)	$PM_{2.5}$ (LUR) controlled for NO_2 (LUR)	Two-Pollutant
	1.143		NO_2 (LUR)*$PM_{2.5}$ (LUR)	