Supplemental Material: Chapter 9 (Reproductive and Developmental Effects) Integrated Science Assessment for Particulate Matter

2019

Center for Public Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC

Contents

Supplemental Tables for Chapter 9 (Reproductive and Developmental Effects)

Table S9-1. Epidemiologic Studies of Fertility and Maternal Health during Pregnancy

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Short Term Exposures			
†Saenen et al. (2015) Genk, Belgium February 2010 – March 2012 Cohort	ENVIRONAGE N = 247 mother-infant pairs	Spatiotemporal interpolation: kriging using land cover and monitor data Means: 15 – 18.7	Placental gene expression, multiple gene models AKT cascade M1: -0.03 (-0.07, 0.0009) T1: -0.03 (-0.08, 0.02) T2: 0.02 (-0.03, 0.07) T3: -0.03 (-0.09, 0.02) SOS cascade M1: -0.1 (-0.2, -0.07) T1: -0.15 (-0.2, -0.08) T2: -0.05 (-0.2, 0.04) T3: -0.09 (-0.2, 0.02) PLCG cascade M1: -0.08 (-0.1, -0.03) T1: -0.1 (-0.2, -0.03) T2: 0.02 (-0.09, 0.1) T3: -0.09 (-0.2, 0.01) Other results reported as figures
†Lee et al. (2011b) Allegheny county, PA, U.S. 1999 – 2001 Cohort	N = 1084 pregnancies	Monitors Mean: 16.4	C-RP concentration <8ng/mL v. >= 8ng/mL (RR) 8 day average: 1.17 (1.02, 1.35) 22 day average: 1.31 (1.05, 1.64) 29 day average: 1.26 (0.97, 1.63) lag 0: 0.99 (0.88, 1.11) lag 1: 1.05 (0.92, 1.21) lag 2: 1.11 (0.97, 1.27) lag 3: 1.02 (0.91, 1.14) lag 4: 1.07 (0.93, 1.23) lag 5: 1.11 (0.97, 1.26) lag 6: 1.03 (0.89, 1.20) lag 7: 1.03 (0.88, 1.21) Nonsmokers only 8 day average: 1.14 (0.91, 1.43) 22 day average: 1.52 (1.14, 2.05) 29 day average: 1.52 (1.05, 2.19) Nonsmokers, no environmental tobacco smoke 8 day average: 1.06 (0.70, 1.60) 22 day average: 1.20 (0.69, 2.08) 29 day average: 1.33 (0.73, 2.40)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Männistö et al. (2015) United States 2002 – 2008 Cohort	N = 223, 502 deliveries	Model, specialized CMAQ, bias corrected with monitor data Averaged over delivery hospital referral region Mean: 9.9	Reported as figures, single day lags 0 to 7
†Männistö et al. (2014) United States 2002 – 2008 Cohort	N = 151,276 births	Model, specialized CMAQ, bias corrected with monitor data Averaged over delivery hospital referral region Mean: NR	Higher blood pressure category at delivery (RR) Normotensive H0: 1.00 (1.00, 1.01) H1: 1.00 (1.00, 1.01) H2: 1.00 (1.00, 1.01) H3: 1.00 (1.00, 1.01) H4: 1.00 (1.00, 1.01) Gestational hypertensive H0: 1.03 (0.99, 1.07) H1: 1.03 (1.00, 1.07) H2: 1.04 (1.00, 1.08) H3: 1.03 (0.99, 1.07) H4: 1.03 (0.99, 1.07) Preeclampsia H0: 1.02 (0.99, 1.05) H1: 1.02 (0.99, 1.05) H2: 1.02 (0.99, 1.05) H3: 1.02 (0.99, 1.05) H4: 1.02 (0.99, 1.05) Chronic hypertensive H0: 0.97 (0.92, 1.02) H1: 0.97 (0.92, 1.02) H2: 0.97 (0.92, 1.02) H3: 0.97 (0.92, 1.02) H4: 0.99 (0.94, 1.04) Superimposed preeclampsia 1.07 (0.96, 1.20) 1.08 (0.97, 1.21) 1.09 (0.98, 1.21) 1.08 (0.97, 1.20) 1.08 (0.98, 1.19)
Long Term Exposures			
†Nieuwenhuijsen et al. (2014) Barcelona, Spain 2011 – 2012 Cross-sectional	N = 1061 census tracts	Land use regression Mean: 17.12	Fertility (IRR, lower = worse) 0.97 (0.91, 1.03)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Slama et al. (2013) Czech Republic 1994 – 1999 Cohort	N = 1,916 couples	Central Site Monitor Mean:	Fecundability (FR) 1st month unprotected intercourse: 0.98 (0.93, 1.03) 30 days before initiation of unprotected intercourse: 0.93 (0.88, 0.98) 30 days before to 1 month after initiation of unprotected intercourse: 0.88 (0.81, 0.97) 1 month post-outcome: 1.02 (0.96, 1.08)
†Mahalingaiah et al. (2014) United States 1993 – 2007 Cohort	Nurses Health Study N = 84,060 women	Spatiotemporal models Monthly average Mean: 15.4	Endometriosis (OR) 2 year average lag: 0.97 (0.91, 1.05) 4 year average lag: 0.96 (0.89, 1.03) Cumulative average: 0.95 (0.89, 1.02)
†Mahalingaiah et al. (2016) United States 1993 – 2007 Cohort	Nurses Health Study N = 36,294	Spatiotemporal models Monthly average Mean: 14.5	Infertility (OR) 2 years prior: 0.99 (0.93, 1.06) 4 years prior: 0.95 (0.88, 1.02) Cumulative from 1989: 1.02 (0.96, 1.10)
†Hansen et al. (2010) Wake County, NC; Shelby County, TX; Galveston County, TX, U.S. 2002 – 2004 Cohort	Healthy Men Study N = 228 presumed fertile men	Monitors Exposure over 90 days before sample Means: 10.9 - 14.2	Sperm concentration (Δ millions/mL): 0.08 (-0.48, 0.65) Sperm count (Δ millions/sample): 0.31 (-0.25, 0.87) Percent normal morphology (Δ): 0.55 (-0.28, 1.37) Percent abnormal morphology (Δ): -0.29 (-0.72, 0.15) Percent abnormal head (Δ): 0.14 (-0.31, 0.58) Percent abnormal midsection (Δ): -0.63 (-1.28, 0.03) Percent abnormal tail (Δ): -0.60 (-1.23, 0.03) Percent cytoplasmic droplets (Δ): 2.37 (-0.04, 4.78) Percent chromomycin A3 staining (Δ): 0.28 (-0.33, 0.88) Percent sperm chromatin structure assay–DNA fragmentation index (Δ): -0.54 (-1.15, 0.08)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Radwan et al. (2015) Lodz, Poland Cohort	Environmental factors and male infertility N = 327 men attending an infertility clinic	Monitor, nearest to zip code Exposure over 90 days before sample Mean: 34.52	Log concentration (million/mL): -0.20 (-2.60, 2.20) Motility (%): -17.90 (-39.50, 3.75) Sperm w/abnormal morphology: 167.10 (120.00, 214.20) Straight-line velocity (um/s): -3.30 (-8.25, 34.90) Curvilinear velocity (um/s): 29.85 (-4.05, 63.70) Linearity (%): 0.55 (-0.95, 2.05) Log follicle stimulating hormone (mIU/mL): 0.65 (-0.45, 1.80) Estradiol (pg/mL): -8.10 (-10.55, 26.70) Testosterone (ng/mL): -2.45 (-6.30, 1.35) Log DNA fragmentation index (%): 0.25 (-1.65, 1.20) High DNA stability (%) - immature cells: 1.80 (0.85, 2.75)
†Hammoud et al. (2009) Salt Lake City, Utah, U.S. 2002 – 2007 Cohort	N = 1,699 semen analyses, 877 inseminations	Monitors Monthly average Mean: NR	Sperm motility (Δ % (p-value)) lag 0 months: 0.053 (0.606) lag 1 month: 0.1105 (0.278) lag 2 months: -0.1715 (0.093) lag 3 months: -0.2035 (0.039) lag 4 months: -0.0405 (0.69) Sperm concentration (Δ Mil/mL (p-value)) lag 0 months: -0.041 (0.68) lag 1 month: 0.174 (0.07) lag 2 months: -0.1425 (0.159) lag 3 months: 0.005 (0.958) lag 4 months: -0.0595 (0.535) Sperm Morphology (Δ % (p-value)) lag 0 months: 0.0075 (0.944) lag 1 month: 0.1665 (0.098) lag 2 months: -0.0295 (0.776) lag 3 months: 0.014 (0.894) lag 4 months: 0.0405 (0.693)
†Fleisch et al. (2014) Boston, MA, U.S. 1999 – 2002 cohort	N = 2,093 women	Central site monitor, within 40km Exposure averaged over T2 Mean: 10.9 Spatio-temporal model using satellite data Exposure averaged over T2 Mean: 11.9	Oral glucose challenge test/oral glucose tolerance test (OR) Central site: 1.51 (0.81, 2.75) Spatio-temporal model: 1.21 (0.65, 2.32) Impaired glucose tolerance (OR) Central site: 1.21 (0.65, 2.32) Spatio-temporal model: 2.37 (0.94, 6.01) Gestational diabetes mellitus (OR) Central site: 3.44 (1.30, 9.11) Spatio-temporal model: 0.54 (0.25, 1.25)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Hu et al. (2015) Florida, U.S. 2004 – 2005 cohort	N = 410,267 women	EPA's hierarchical bayesian space-time statistical model (fused CMAQ) Means: 9.74 – 10.03	Gestational diabetes (OR) EP: 1.16 (1.11, 1.21) T1: 1.15 (1.10, 1.20) T2: 1.20 (1.13, 1.26) Adjusted for O3 EP: 1.11 (1.06, 1.16) T1: 1.02 (0.98, 1.07) T2: 1.10 (1.04, 1.16)
†Robledo et al. (2015) United States 2002 – 2008 cohort	N = 219,952 pregnancies	Model, specialized CMAQ, bias corrected with monitor data Averaged over delivery hospital referral region Median: 11.71	Gestational diabetes (OR) 3 months preconception: 0.97 (0.94, 1.02) T1: 0.98 (0.94, 1.03)
†Fleisch et al. (2016) MA, U.S. 2003 – 2008 cohort	N = 159,373 women	Satellite-based spatiotemporal model, 1 km grid Mean: 10.4	Gestational diabetes (OR) T1 Q1, 3.1-9.3: ref Q2, 9.3-10.4: 1.00 (0.93, 1.09) Q3, 10.4-11.5: 0.97 (0.89, 1.05) Q4, 11.5 - 17.1: 1.00 (0.92, 1.09) T2 Q1, 1.3-9.2: ref Q2, 9.2-10.4: 1.04 (0.96, 1.13) Q3, 10.4-11.6: 0.95 (0.88, 1.03) Q4, 11.6-19.3: 0.99 (0.91, 1.08)
†Xu et al. (2014) Jacksonville, Fl, U.S. 2004 – 2005 cohort	N = 22,041 women	Monitor, nearest within 20km Mean: 10.01 – 10.44	Hypertensive disorders of pregnancy (OR) T1: 1.09 (0.99, 1.20) T2: 1.24 (1.11, 1.39) EP: 1.20 (1.07, 1.36)
†Lee et al. (2012b) Allegheny County, PA, U.S. 1997 – 2001 Cohort	N = 1,684 women	Space-time ordinary kriging, zip code centroid Mean: 18.1	Blood pressure before 20 weeks compared to late pregnancy (Δ mmHg) Systolic: 0.53 (-0.87, 1.92) Diastolic: 0.50 (-0.54, 1.55) Non-smokers Systolic: 1.11 (-0.43, 2.63) Diastolic: 0.79 (-0.36, 1.93)
†Lee et al. (2013) Pittsburgh, PA, U.S. 1997 – 2002 Cohort	N = 34,705 women	Space-time ordinary kriging, zip code centroid Mean: 15.6	Preeclampsia (OR) T1: 1.19 (0.95, 1.51) Gestational hypertension (OR) T1: 1.14 (1.00, 1.30)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Dadvand et al. (2013a) Barcelona, Spain 2000 – 2005 Cohort	N = 8,398 pregnancies, 103 cases	Land use regression Means: 16.5 – 17.3	Preeclampsia (OR) EP: 1.31 (1.02, 1.69) T1: 1.18 (0.96, 1.45) T2: 1.08 (0.90, 1.30) T3: 1.33 (1.09, 1.61) Early onset preeclampsia, diagnosed at 20-34 weeks (OR) EP: 1.52 (0.94, 2.45) T1: 1.41 (0.95, 2.08) T2: 1.26 (0.88, 1.81) T3: 1.19 (0.80, 1.78) Late onset preeclampsia, diagnosed after 34 weeks (OR) EP: 1.18 (0.87, 1.59) T1: 1.09 (0.86, 1.40) T2: 1.03 (0.82, 1.28) T3: 1.27 (1.01, 1.61)
†Dadvand et al. (2014b) Barcelona, Spain 2003 – 2005 Cohort, hospital based	N = 3,182 women	Positive Matrix Factorization Mean: 32.5	Preeclampsia (OR) EP: 0.63 (0.39, 1.03) PM2.5 from traffic related sources only, EP: 1.06 (0.44, 2.50)
†Rudra et al. (2011) Washington, U.S. 1996 – 2006 Cohort	N = 732,732 women	Land use regression Mean: 10.8	Preeclampsia (OR) 7 months around conception: 1.22 (0.48, 3.11)
†Jedrychowski et al. (2012) Krakow, Poland Cohort	N = 431 women	Personal monitor Over 2 days in the 2nd trimester Mean: 33.6	Blood pressure in 3rd trimester (Δ mmHg), per 1-log unit increase in PM2.5 Systolic: 6.126 (0.610, 11.642) Diastolic: 4.083 (-0.019, 8.185)
†Vinikoor-Imler et al. (2012) North Carolina, U.S. 2000 – 2003 Cohort	N = 222,775 women	Monitor Means: 22.2 – 22.4	Hypertensive disorders of pregnancy (OR) EP: 1.26 (1.19, 1.37)
†Wu et al. (2009) LA and Orange Counties, CA, U.S. 1997 – 2006 Cohort	N = 81,186	CALINE4 line-source dispersion model Mean: 1.82	Preeclampsia (OR) EP: 1.47 (1.24, 1.68)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Wu et al. (2011) LA and Orange Counties, CA, U.S. 1997 – 2006 Cohort	N = 81,186	CALINE4 line-source dispersion model Mean: 1.82 Monitor Mean: 17.3	Preeclampsia (OR) Monitor LA: 0.59 (0.31, 1.05) Orange: 0.90 (0.53, 1.54) CALINE4 LA: 1.47 (1.10, 2.01) Orange: 1.61 (1.22, 2.19)
†Savitz et al. (2015) New York, NY, U.S. 2008 – 2010 Cohort	N = 268, 601	Land use regression Mean: NR	Total hypertensive disorders (OR) T1: 0.96 (0.93, 1.00) T2: 0.95 (0.92, 0.99) Gestational hypertension (OR) T1: 0.98 (0.93, 1.05) T2: 0.94 (0.88, 1.00) Mild preeclampsia (OR) T1: 0.94 (0.88, 1.00) T2: 0.95 (0.89, 1.00) Severe preeclampsia/eclampsia T1: 0.97 (0.91, 1.05) T2: 0.98 (0.90, 1.05)
†Mendola et al. (2016b) United States 2002 - 2008	N = 210,508 deliveries	Model, specialized CMAQ, bias corrected with monitor data Averaged over delivery hospital referral region Mean: 11.8	Preeclampsia (OR) Women with asthma preconception (90 days): 0.95 (0.86, 1.06) T1: 1.02 (0.93, 1.15) T2: 0.99 (0.91, 1.13) EP: 1.01 (0.93, 1.26) Women without asthma preconception (90 days): 0.97 (0.94, 1.02) T1: 1.03 (0.94, 1.04) T2: 1.02 (0.95, 1.04) EP: 1.04 (0.94, 1.12)
†Mobasher et al. (2013) Los Angeles County, CA, U.S. 1996 - 2008	N = 298 women	Monitors Mean (SD): 17 (3.5)	Hypertensive disorders of pregnancy (OR) T1: 2.66 (1.53, 4.63) T2: 1.56 (0.96, 2.51) T3: 1.30 (0.82, 2.03) BMI < 30 T1: 4.66 (2.24, 9.72) T2: 1.49 (0.81, 2.70) T3: 1.19 (0.69, 2.08) BMI >= 30 T1: 0.79 (0.25, 2.48) T2: 1.87 (0.74, 4.71) T3: 1.27 (0.46, 3.42)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Saenen et al. (2015) ZOL, Genk, Belgium Feb 2010 - Mar 2012 Cohort	ENVIRONAGE N = 247 mother-infant pairs	Spatiotemporal interpolation model (kriging, using land cover and monitor data) Means: 15 – 18.7	AKT cascade (BDNF, AKT1, AKT2, AKT3) M1: -0.03 (-0.07, 0.00) T1: -0.03 (-0.08, 0.02) T2: 0.02 (-0.03, 0.07) T3: -0.03 (-0.09, 0.02) SOS cascade (BDNF, SOS1, SOS2, SYN1) M1: -0.10 (-0.20, -0.07) T1: -0.15 (-0.20, -0.08) T2: -0.05 (-0.20, 0.04) T3: -0.09 (-0.20, 0.02) PLCG cascade (BDNF, PLCG1, PLCG2) M1: -0.08 (-0.10, -0.03) T1: -0.10 (-0.20, -0.03) T2: 0.02 (-0.09, 0.10) T3: -0.09 (-0.20, 0.01)
†Saenen et al. (2016) ZOL, Genk, Belgium 2010 – 2013 Cohort	ENVIRONAGE N = 330	Spatiotemporal interpolation model (using land cover, monitor, and dispersion data) Mean: 16.1	Placental 3-NTp, biomarker of oxidative stress (% change) EP: 50.00 (19.86, 85.71) T1: 16.48 (2.78, 33.30) T2: 26.55 (8.31, 49.12) T3: 7.02 (-5.00, 21.97)
†Nachman et al. (2016) Boston, MA, U.S. 1999 – 2012 Cohort	Boston Birth Cohort N = 5,059 mothers	Monitor, nearest no distance limit	Intrauterine inflammation (OR) preconception (90 days): 1.07 (0.96, 1.20) T1: 1.42 (1.26, 1.60) T2: 1.45 (1.29, 1.64) T3: 1.12 (1.00, 1.26) EP: 1.68 (1.47, 1.92) Last month: 1.15 (1.04, 1.26)
†Lavigne et al. (2016a) Canada 2008 – 2011 Cohort	MIREC Study N = 1,257 mother-infant pairs	Land use regression, satellite and monitor based Monthly average Exposures averaged over entire pregnancy Mean: 8.3	Fetal leptin (% change) 17.19 (1.56, 32.81) Fetal adiponectin (% change) 17.19 (6.25, 26.56)
†Janssen et al. (2016) Limburg, Belgium 2010 – 2014 Cohort	ENVIRONAGE N = 431 newborns	Spatiotemporal interpolation model (using land cover, monitor, and dispersion data) Mean: 16	Fetal thyroid stimulating hormone (% change) T3: -7.07 (-13.29, -0.06) Fetal FT4/FT3 ratio (% change) T3: -38.23 (-55.85, -20.61)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Herr et al. (2010) Czech Republic 1994 – 1999 Cohort	N = 1,397 mother-infant pairs	Monitor Mean: 26.9	Umbilical cord CD3+ (% change) M1: 0.50 (0.14, 0.84) M7: -0.50 (-0.18, -0.84) Umbilical cord CD4+ (% change) M1: 0.44 (0.14, 0.74) M7: -0.40 (-0.12, -0.68)

†Studies published since the 2009 PM Integrated Science Assessment.

[a]All estimates reported per 5µg increase in $PM_{2.5}$ unless otherwise stated.

CI = confidence interval; CMAQ = community multiscale air quality modeling system; C-RP = C-reactive protein; EP = entire pregnancy; FR = fecundity ratio; IRR = incidence rate ratio; M1 = 1st month of pregnancy; M7 = 7th month of pregnancy; OR = odds ratio; RR = risk or rate ratio; T1 = 1st trimester of pregnancy; T2 = 2nd trimester of pregnancy; T3 = 3rd trimester of pregnancy.

Table S9-2. Epidemiologic Studies of Fetal Growth

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Jedrychowski et al. (2017) Krakow, Poland Follow-up: 2000-2004 Prospective Pregnancy Cohort	455 healthy women (18-35 years) who delivered between 34 and 42 weeks	Personal monitor worn for 2 days during second trimester	Birth Length (cm) -0.11 (p=0.017) per 1 StDev in ln-transformed PM2.5 concentration Head Circumference (cm) -0.11 (p=0.014) per 1 StDev in ln-transformed PM2.5 concentration
Bell et al. (2010) CT and MA 2000-2004	76,788 births recorded by the National Center for Health Statistics, with a gestation period between 37 and 44 weeks	Measurements from PM2.5 regulatory monitors during the pregnancy	BW (change in grams) Total pregnancy: -8 (-25, 6) 1st trimester: -3 (-17, 14) 2nd trimester: 0 (-14, 14) 3rd trimester: -6 (-22, 8) Percent Increase, Risk of Small-at-term Birth: 19 (-3, 47)
Darrow et al. (2011) Atlanta, GA 1994-2004	406,267 births with a gestation period of at least 37 weeks in the five central counties of the Atlanta metropolitan area	Modeled data from PM2.5 monitor measurements over the course of the pregnancy	BW (change in grams) First month: 0 (-7.4, 7.4) Third trimester: -10.8 (-24.5, 3.0)
Erickson et al. (2016) British Columbia, Canada 2001-2006	231,929 live and still-born birth records	National PM2.5 land-use regression model	BW (modeled effect on birth weight) β = -239 (-265, -213)
†Fleisch et al. (2015) Boston, MA Follow-up: NR Pregnancy Cohort	2,115 singleton live births to mothers enrolled in Project Viva cohort study	Satellite-based predictions from modeling approach (see Kloog et al. (2011)) averaged over third trimester	Birth Weight for Gestational Age (BWGA) z-score; Third Trimester Q1: 1.00 (referent) Q2: -0.02 (-0.14, 0.10) Q3: 0.03 (-0.09, 0.15) Q4: -0.08 (-0.2, 0.04)
Geer et al. (2012) Texas 1998-2004	1,548,904 birth records with gestational period between 47 and 44 weeks	Average PM2.5 monitor measurements by county of residence	BW (change in grams) Gestational period: 24.9 (5.8, 44.1)
Gehring et al. (2014) Vancouver, Canada 1999-2002	68,238 singleton births	PM2.5 land-use regression model	BW (change in grams) Entire pregnancy: -31 (-51, -11) PTB (OR) Moderately PTB: 1.00 (0.82, 1.34) Very PTB: 1.97 (1.00, 4.05)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Gehring et al. (2011) Netherlands 1996-1997 Pregnancy Cohort	3,853 births in the prospective Prevention and Incidence of Asthma and Mite Allergy (PIAMA) cohort	PM2.5 land-use regression model	BW (change in grams) Entire pregnancy: 65.2 (-15.4, 145.9) 1st trimester: 22.4 (-8.7, 53.4) Final month: -26.0 (-66.0, 14.0) PTB (OR) Entire pregnancy: 1.54 (0.67, 3.59) 1st trimester: 0.97 (0.69, 1.39) Final month: 1.12 (0.72, 1.76)
Gray et al. (2010) North Carolina 2000-2002	350,754 births from mothers between 15 and 44 years of age, with between 32 and 44 weeks of gestation and with no congenital anomalies	County-level measures from EPA Air Quality System PM2.5 monitors	BW (change in grams) Entire pregnancy: 28.8 (14.4, 42.5) Third trimester: 33.6 (20.7-46.5) (Other results not reported)
Hannam et al. (2014) Northwest England 2004-2008	203,562 births in the NW Perinatal Survey Unit cohort	Spatio-temporal (S-T) model, Nearest stationary monitor technique (NSTAT)	BW (change in grams) S-T: 11 (-24, 48) NSTAT: 18, (-302, 336)
†Hyder et al. (2014) CT & MA, US Follow-up: 2000-2006 Birth Cohort Study	662,921 births, 2% term LBW, 10% SGA	Weekly averages from closest ground monitors within 50 km of maternal residence Satellite-based predictions from calibration and modeling approach (see Lee et al. (2012a; Lee et al. (2011a)	Term BW; Entire Pregnancy Monitor: -12.9 (-16.4, -9.5) Satellite 1: -32.6 (-42.5, -22.4) Satellite 2: -93.4 (-47.7, -30.9)
Jedrychowski et al. (2010) NYC, NY and Krakow, Poland 2001-2004	481 women who gave birth after 36 weeks of gestation	Personal monitor worn for 2 days during second trimester	BW -1.01 (-83.19, 81.17) for PM2.5 exposure in second tertile (27.0 - 46.29 µg/m³) relative to first tertile -97.02 (-185.67, -8.37) for PM2.5 exposure in third tertile (> 46.29 µg/m³) relative to first tertile
Jedrychowski et al. (2017) Krakow, Poland Follow-up: 2000-2004 Prospective Pregnancy Cohort	455 healthy women (18-35 years) who delivered between 34 and 42 weeks	Personal monitor worn for 2 days during second trimester	Term BW -0.10 g (p=0.023) per 1 StDev in ln-transformed PM2.5 concentration

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Keller et al. (2017) Georgia, U.S. Follow-up: 2002-2005 Birth Cohort Study	403,881 births statewide; 180,440 births in counties with PM2.5 monitor	Bootstrap-based exposure measurement error correction methods applied to spatiotemporal predictions (1 km grid cells) averaged over trimesters	Term BW Residing in county with PM2.5 monitor T1: -7.5 (-15.5, 0.5) T2: -8.0 (-16.0, 0.0) T3: -12.0 (-19.5, -4.0) Bootstrap correction for exposure measurement error T1: -7.5 (-17.5, 0.5) T2: -8.0 (-16.5, 0.0) T3: -12.5 (-21.0, -4.0)
†Kloog et al. (2012) Massachusetts, US Follow-up: 2000-2008 Birth Cohort Study	634,844 singleton live births from MA Birth Registry	Satellite-based predictions from modeling approach (see Kloog et al. (2011; Lee et al. (2011a)	Term BW Entire Pregnancy: -4.40 (-5.16, -2.22) 30 days before birth: -4.6 (-7.5, -1.65) 90 days before birth: -7.9 (-10.55, -3.03)
†Lakshmanan et al. (2015) Boston, MA Follow-Up: 2002-2009 Pregnancy Cohort Study	955 singleton births to mothers enrolled in Asthma Coalition on Community, Environment, and Social Stress (ACCESS) cohort	Satellite-based predictions from modeling approach (see Kloog et al. (2011)) averaged over entire pregnancy	Birth Weight for Gestational Age (BWGA) z-score; Entire Pregnancy 0.16 (-0.33, 0.63)
†Laurent et al. (2013) Los Angeles, CA 1997-2006 Birth Cohort Study	61,623 term births from network of four hospitals in LA and Orange counties	Ground monitors (closest monitor), CALINE 4 dispersion model; averaged for each month	Ground Monitor Birth Weight Entire Pregnancy: 26.83 (21.56, 32.11) CALINE Birth Weight Entire Pregnancy: 21.8 (15.78, 35.18)
Madsen et al. (2010) Oslo, Norway 1999-2002	25,229 singleton birth records with weight of at least 1000 grams	EPISODE dispersion model	BW (change in grams relative to lowest quartile exposure, < 9.7 μg/m³) Q2 (9.1-11.5 μg/m³): 0.8 (-14.5, 16.0) Q3 (11.6-14.1 μg/m³): 16.3 (0.8, 31.7) Q4 (> 14.1 μg/m³): 13.6 (-2.4, 29.5)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Morello-Frosch et al. (2010) California 1996-2006	3,545,177 singleton births from tracts or ZIP codes within 10 km of a monitor	Monitors from either EPA Air Quality System of CalAIRS	BW (change in grams) Within 3 km of monitor: -9.2 (-12.5, -5.9) 5 km: -11.4 (-13.5, -9.3) 10 km: -12.8 (-14.3, -11.3)
Parker and Woodruff (2008) United States 2001-2003	401,273 births recorded by the national Center for Health Statistics	County averages of monitors from EPA Air Quality System	BW (change in grams) Unadjusted: 19.4 (9.8, 29.0) Fully adjusted: 4.6 (-6.1, 15.3)
Pedersen et al. (2013) 12 European countries 1994-2011	74,178 births in the European Study of Cohorts for Air Pollution Effects (ESCAPE)	Land-use regression models	BW [Tom—seems like only LBW reported?]
Slama et al. (2010) Germany 1997-1999	992 genotyped singleton births in the LISA cohort	Land-use regression model	BW (change in grams, above median exposure compared to below median exposure, 14.4 µg/m³) -22 (-99, 55)
†Stieb et al. (2015) Multicity, Canada Follow-up: 1999-2008 Birth Cohort Study	3 million singleton live births; 1.57% term LBW and 8.31% SGA	Hybrid of ground monitors, LUR and remote sensing (satellite images) described in Beckerman et al. (2013)	Term BW; Entire Pregnancy -20.5 (-24.7, -16.4) grams
Tu et al. (2016) Georgia 2000	105,818 singleton full-term births in the Georgia Vital Records Office	EPA Fused Air Quality Predictions Surface model	BW [Tom—not sure how you want to present this study's results]
Vinikoor-Imler et al. (2014) North Carolina 2003-2005	297,043 births in North Carolina State Center for Health Statistics records	Bayesian model from EPA Air Quality System monitors and CMAQ model	BW (change in grams per IQR = 3.5 µg/m³) Trimester 1: 12.66 (4.57, 20.71) Trimester 2: 0.94 (-7.00, 8.89) Trimester 3: 6.11 (-1.66, 13.86)
†Brauer et al. (2008) Vancouver, BC Follow-up: 1999-2002 Birth Cohort Study	70,249 live births in study area with data on residential history	IDW based on ground-monitors (n=7) assigned to postal codes LUR (R^2=0.52), cross-validation revealed poor performance of $PM_{2.5}$ LUR model	Term LBW; Entire Pregnancy IDW: 0.91 (0.68, 1.25) LUR: 1.10 (0.97, 1.25)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Brown et al. (2015) New York, USA 2001-2006	480,430 births; 9,782 term LBW	Hierarchical Bayesian spatio-temporal model incorporating CMAQ data	TLBW (OR relative to Q1 exposure) First trimester, Q2: 0.97 (0.91, 1.03) First trimester, Q3: 0.94 (0.88, 1.00) First trimester, Q4: 0.97 (0.91, 1.04) Second trimester, Q2: 0.97 (0.91, 1.04) Second trimester, Q3: 0.96 (0.90, 1.02) Second trimester, Q4: 0.99 (0.93, 1.06) Third trimester, Q2: 0.97 (0.91, 1.03) Third trimester, Q3: 0.94 (0.88, 1.00) Third trimester, Q4: 0.97 (0.93, 1.06) Entire pregnancy, Q2: 0.95 (0.89, 1.01) Entire pregnancy, Q3: 0.92 (0.86, 0.98) Entire pregnancy, Q4: 0.97 (0.91, 1.04)
Cândido da Silva et al. (2014) Mato Grosso, Brazil 2004-2005	6,147 full-term singleton births	Model incorporating emissions from Amazonian biomass burning	LBW (OR relative to Q1 exposure) First trimester, Q2: 0.95 (0.68, 1.33) First trimester, Q3: 1.31 (0.92, 1.88) First trimester, Q4: 1.02 (0.74, 1.42) Second trimester, Q2: 1.06 (0.76, 1.47) Second trimester, Q3: 1.22 (0.87, 1.71) Second trimester, Q4: 1.51 (1.04, 2.17) Third trimester, Q2: 1.01 (0.73, 1.38) Third trimester, Q3: 1.18 (0.83, 1.70) Third trimester, Q4: 1.50 (1.06, 2.15) Entire pregnancy, Q2: 0.95 (0.69, 1.31) Entire pregnancy, Q3: 1.20 (0.85, 1.69) Entire pregnancy, Q4: 1.33 (0.92, 1.90)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Dadvand et al. (2013b) International meta-analysis in 9 countries—PM2.5 data available for USA, Netherlands, Canada 1962-2006	Approximately 3 million births total in 14 centers	Varying by study	LBW (OR) Adjusted for maternal SES: 1.10 (1.03, 1.18) + Center-specific covatiates: 1.04 (0.99, 1.09)
Dadvand et al. (2014c) Barcelona, Spain 2001-2005	6,438 singleton term births	Land-use regression models at maternal residence	LBW (OR) Entire pregnancy (IQR = 3.1 μg/m³): 1.66 (0.94, 2.89) First trimester (IQR = 3.7 μg/m³): 1.20 (0.71, 1.99) Second trimester (IQR = 3.7 μg/m³): 1.60 (0.92, 2.73) Third trimester (IQR = 3.6 μg/m³): 1.82 (1.09, 3.03)
Ebisu and Bell (2012) Northeastern and mid-Atlantic United States 2000-2007	1,207,800 births in CT, DE, MD, MA, NH, NJ, NY, PA, RI, VT, VA, WV, and DC	County averages from monitors	LBW (Percent risk per IQR = 2.71 μg/m³) All data: 8.1 (-0.7, 17.7) First births only: 11.8 (-2.6, 26.9)
Fleischer (2014) 22 countries in Africa, Asia, and Latin America 2004-2008	192,900 live births in the WHO Global Survey on Maternal and Perinatal Health	Long-term averages from remote sensing data	LBW (OR) 0.99 (0.96, 1.01) PTB (OR) 0.96 (0.90, 1.02)
Gray et al. (2014) North Carolina 2002-2006	457,642 births to Nonhispanic White, Nonhispanic Black, and Hispanic women	Bayesian downscaling fusion model	BW (change in grams) -13.61 (-14.52, -12.74) LBW (OR) 1.09 (0.96, 1.19) SGA (OR) 1.16 (1.10, 1.28) PTB (OR) 1.04 (0.96, 1.09)
†Ha et al. (2014) Florida, US Follow-up: 2004-2005 Birth Cohort Study	423,719 singleton live births; 2.4% term LBW	HBM CMAQ predictions for 2003-2005 at maternal residence	Term LBW Entire pregnancy: 1.04 (0.97, 1.11) T1: 1.01 (0.96, 1.07) T2: 1.07 (1.01, 1.12) T3: 1.01 (0.96, 1.06)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Ha et al. (2017) Multi-city, U.S. Follow-up: 2002-2008 Birth Cohort Study	220,572 births, 11.2% SGA; 2.2% term LBW	Population-weighted CMAQ predictions corrected using IDW to local monitors	Term LBW Entire pregnancy: 1.10 (0.97, 1.26) T1: 1.08 (0.99, 1.17) T2: 1.01 (0.93, 1.10) T3: 0.93 (0.86, 1.01)
Harris et al. (2014) 7 states in the United States 2001-2004	1,374,875 births in CT, ME, MN, NJ, NY, UT, WI	Community Multi-scale Air Quality (CMAQ) model	LBW (OR) Full pregnancy: 1.34 (1.24, 1.44) T1: 1.20 (1.14, 1.24) T2: 1.13 (1.07, 1.18) T3: 1.09 (1.05, 1.15)
†Hyder et al. (2014) CT & MA, US Follow-up: 2000-2006 Birth Cohort Study	662,921 births, 2% term LBW, 10% SGA	Weekly averages from closest ground monitors within 50 km of maternal residence Satellite-based predictions from calibration and modeling approach (see Lee et al. (2012a; Lee et al. (2011a)	Term LBW; Entire Pregnancy Monitor: 1.02 (0.96, 1.08) Satellite 1: 1.13 (0.94, 1.36) Satellite 2: 1.17 (1.02, 1.36)
Laurent et al. (2014) Los Angeles County, CA 2001-2008	960,945 singleton births between 260 and 208 estimated days of gestation	Bayesian model using California Air Resources Board monitors	LBW (OR) 1.03 (1.02, 1.05)
†Laurent et al. (2013) Los Angeles, CA 1997-2006 Birth Cohort Study	61,623 term births from network of four hospitals in LA and Orange counties	Ground monitors (closest monitor), CALINE 4 dispersion model; averaged for each month	Ground Monitor Term LBW Entire Pregnancy: 0.93 (0.84, 1.02) CALINE Birth Weight Entire Pregnancy: 21.8 (15.78, 35.18)
Lavigne et al. (2016b) Ontario, Canada 2005-2012	818,400 singleton live births	Satellite-based estimates at maternal postal code	LBW (OR) 0.82 (0.69, 0.96) SGA (OR) 0.82 (0.76, 0.88) PTB (OR) 1.22 (1.13, 1.31)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Madsen et al. (2010) Oslo, Norway 1999-2002	25,229 singleton birth records with weight of at least 1000 grams	EPISODE dispersion model	LBW (OR relative to lowest quartile exposure, < 9.7 µg/m³) Q2 (9.7-11.5 µg/m³): 0.9 (0.7, 1.2) Q3 (11.6-14.1 µg/m³): 0.9 (0.6, 1.2) Q4 (> 14.1 µg/m³): 0.9 (0.5, 10) SGA (OR relative to lowest quartile exposure, < 9.7 µg/m³) Q2 (9.7-11.5 µg/m³): 1.0 (0.9, 1.1) Q3 (11.6-14.1 µg/m³): 1.0 (0.8, 1.1) Q4 (> 14.1 µg/m³): 0.9 (0.8, 10)
Morello-Frosch et al. (2010) California 1996-2006	3,545,177 singleton births from tracts or ZIP codes within 10 km of a monitor	Monitors from either EPA Air Quality System of CalAIRS	LBW (OR) Within 3 km of monitor: 1.04 (0.99, 1.09) 5 km: 1.05 (1.02, 1.08) 10 km:1.04 (1.02, 1.07)
Parker and Woodruff (2008) United States 2001-2003	401,273 births recorded by the national Center for Health Statistics	County averages of monitors from EPA Air Quality System	LBW (OR) 1.00 (0.91, 1.10)
Pedersen et al. (2013) 12 European countries 1994-2011	74,178 births in the European Study of Cohorts for Air Pollution Effects (ESCAPE)	Land-use regression models	LBW (OR) All: 1.18 (1.06, 1.33) Mothers exposed to < 15 µg/m³: 1.79 (1.29, 2.48) Mothers exposed to < 20 µg/m³: 1.41 (1.20, 1.65) Mothers exposed to < 25 µg/m³: 1.21 (1.06, 1.38)
†Salihu et al. (2012) Hillsborough County, FL Follow-up: 200-2007 Birth Cohort Study	103,961singleton live births; 6.4% LBW and 8.4% SGA	6-day concentrations from 14 ground monitors; maternal residential ZIP code centroid linked to nearest monitor, based on centroid of ZIP code in which monitor was located; exposure dichotomized at median	ORs for exposure above median compared to below median LBW; Entire Pregnancy 1.07 (1.01, 1.12) Very LBW; Entire Pregnancy 1.14 (1.01, 1.29)
†Stieb et al. (2015) Multicity, Canada Follow-up: 1999-2008 Birth Cohort Study	3 million singleton live births; 1.57% term LBW and 8.31% SGA	Hybrid of ground monitors, LUR and remote sensing (satellite images) described in Beckerman et al. (2013)	Term LBW; Entire Pregnancy 1.01 (0.94, 1.08)
Trasande et al. (2013) United States 2000, 2003, 2006	222,359 births in the Kids Inpatient Database (KID)	EPA AIRS monitors within 10 miles of hospital of birth	LBW (OR) 2.59 (1.79, 3.71) PTB (OR per IQR = 1 µg/m³) 0.74 (0.66, 0.82)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Vinikoor-Imler et al. (2014) North Carolina 2003-2005	297,043 births in North Carolina State Center for Health Statistics records	Bayesian model from EPA Air Quality System monitors and CMAQ model	LBW (OR) Trimester 1: 0.84 (0.76, 0.94) Trimester 2: 0.86 (0.79, 0.97) Trimester 3: 1.03 (0.92, 1.18) SGA (OR) Trimester 1: 0.89 (0.84, 0.94) Trimester 2: 0.92 (0.86, 0.94) Trimester 3: 0.92 (0.86, 0.97)
†Brauer et al. (2008) Vancouver, BC Follow-up: 1999-2002 Birth Cohort Study	70,249 live births in study area with data on residential history	IDW based on ground-monitors (n=7) assigned to postal codes LUR (R2=0.52), cross-validation revealed poor performance of PM2.5 LUR model	SGA; Entire pregnancy IDW: 1.09 (0.91, 1.25) LUR: 1.07 (1.00, 1.10)
†Ha et al. (2017) Multi-city, U.S. Follow-up: 2002-2008 Birth Cohort Study	220,572 births, 11.2% SGA; 2.2% term LBW	Population-weighted CMAQ predictions corrected using IDW to local monitors	SGA Entire pregnancy: 1.01 (0.96, 1.07) T1: 1.00 (0.97, 1.04) T2: 1.02 (0.99, 1.06) T3: 1.00 (0.97, 1.03)
Hannam et al. (2014) Northwest England 2004-2008	203,562 births in the NW Perinatal Survey Unit cohort	Spatio-temporal (S-T) model, Nearest stationary monitor technique (NSTAT)	SGA (OR) S-T: 1.09 (0.85. 1.41) NSTAT: 3.04 (1.32, 7.11) PTB (OR) S-T: 0.96 (0.70, 1.28) NSTAT: 0.15 (0.04, 0.69)
†Hyder et al. (2014) CT & MA, US Follow-up: 2000-2006 Birth Cohort Study	662,921 births, 2% term LBW, 10% SGA	Weekly averages from closest ground monitors within 50 km of maternal residence Satellite-based predictions from calibration and modeling approach (see Lee et al. (2012a; Lee et al. (2011a)	SGA; Entire Pregnancy Monitor: 1.06 (1.02, 1.08) Satellite 1: 1.13 (1.06, 1.22) Satellite 2: 1.17 (1.08, 1.24)
Lee et al. (2013) Allegheny County, PA 1997-2002	34,705 deliveries at Magee-Women's Hospital in Pittsburgh, PA	Model using EPA and Allegheny County Health Department monitors	SGA (OR) Overall: 1.08 (0.86, 1.33) Mother smoked during pregnancy: 0.98 (0.73, 1.33) Mothers did not smoke: 1.03 (0.79, 1.33)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Rich et al. (2009) New Jersey 1999-2003	178,198 birth certificates and maternal/newborn hospital discharge summaries	Measurement from closest PM2.5 monitor to maternal residence (excluded if >10 km away)	SGA (Percent change in risk) T1: 11.3 (1.3, 21.8) T2: -4.5 (-14.0, 5.5) T3: 10.3 (0.8, 20.0) VSGA (Percent change in risk) T1: 6.5 (-11.0, 25.0) T2: 0.5 (-16.8, 18.8) T3: 10.5 (-6.0, 28.0)
†Salihu et al. (2012) Hillsborough County, FL Follow-up: 200-2007 Birth Cohort Study	103,961singleton live births; 6.4% LBW and 8.4% SGA	6-day concentrations from 14 ground monitors; maternal residential ZIP code centroid linked to nearest monitor, based on centroid of ZIP code in which monitor was located; exposure dichotomized at median	ORs for exposure above median compared to below median SGA; Entire pregnancy 1.06 (1.01, 1.11)
†Stieb et al. (2015) Multicity, Canada Follow-up: 1999-2008 Birth Cohort Study	3 million singleton live births; 1.57% term LBW and 8.31% SGA	Hybrid of ground monitors, LUR and remote sensing (satellite images) described in Beckerman et al. (2013)	SGA; Entire pregnancy 1.04 (1.01, 1.07)

†Studies published since the 2009 PM Integrated Science Assessment.
[a]All estimates reported per 5µg increase in $PM_{2.5}$ unless otherwise stated.
CI = confidence interval; CMAQ = community multiscale air quality modeling system; C-RP = C-reactive protein; EP = entire pregnancy; FR = fecundity ratio; IRR = incidence rate ratio; M1 = 1st month of pregnancy; M7 = 7th month of pregnancy; OR = odds ratio; RR = risk or rate ratio; T1 = 1st trimester of pregnancy; T2 = 2nd trimester of pregnancy; T3 = 3rd trimester of pregnancy.

Table S9-3. Studies of Preterm Birth and Premature Rupture of Membranes

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
		Short Term Exposure	
†Darrow et al. (2009) Atlanta, GA, U.S. 1994 – 2004 Time-series	N = 1994 days, 476,789 births	Monitors, daily population weighted spatial averages from 11 monitors Means: 16.4 – 16.5	Preterm birth (RR) 1 week lag: 0.98 (0.97, 1.00) Within 4 miles of monitor 1 week lag: 1.00 (0.97, 1.02)
†Rappazzo et al. (2014) PA, OH, NJ, U.S. 2000 – 2005 Cohort	N = 1,940,213	Fused CMAQ model, northeastern U.S. specific Exposures over each week of gestation Mean: 14.46	Reported as figures

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Warren et al. (2012) Texas, U.S. 2002 - 2004 Cohort	NR	Monitors CMAQ Exposures over each week of gestation Mean: NR	Reported as figures
†Symanski et al. (2014) Harris County, Texas, U.S. 2005 – 2007 Cohort	N = 171, 923	Monitors County average Mean: NR	Severe preterm birth (<28 weeks) weeks 1-4: 1.37 (1.15, 1.64) weeks 5-8: 0.95 (0.77, 1.15) weeks 9-12: 1.13 (0.93, 1.37) weeks 13-16: 0.84 (0.70, 1.01) weeks 17-20: 1.30 (1.07, 1.58) Moderately preterm birth (29-32 weeks) weeks 1-4: 1.38 (1.20, 1.59) weeks 5-8: 1.04 (0.88, 1.23) weeks 9-12: 1.28 (1.09, 1.51) weeks 13-16: 0.98 (0.84, 1.15) weeks 17-20: 0.96 (0.82, 1.13) weeks 21-24: 0.94 (0.80, 1.10) weeks 25-28: 1.39 (1.20, 1.61) Mildly preterm birth (33-36 weeks) weeks 1-4: 1.08 (1.02, 1.13) weeks 5-8: 1.04 (0.98, 1.10) weeks 9-12: 1.12 (1.06, 1.05) weeks 13-16: 0.98 (0.93, 1.03) weeks 17-20: 1.08 (1.01, 1.14) weeks 21-24: 0.91 (0.86, 0.96) weeks 25-28: 1.05 (0.99, 1.11) weeks 29-32: 1.14 (1.08, 1.21)
†Arroyo et al. (2015) Madrid, Spain 2001 – 2009 Time series	N = 3,287 births	Monitors Single day lags Mean: 17.1	Preterm birth per IQR increase (NR) Lag1: 1.04 (1.00, 1.07)
†Arroyo et al. (2016) Madrid, Spain 2004-2009 Time series	N = 314 weeks	Monitors Exposure at each week of pregnancy Mean: 17.1	Preterm birth, only statistically significant lags reported week 17 (lag 20): 1.01 (1.01, 1.02)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Wallace et al. (2016) United States 2002 – 2008 Cohort	N = 223,375	Model, specialized CMAQ, bias corrected with monitor data Averaged over delivery hospital referral region Exposures lagged before hour of admission for delivery Mean: 11.9	Preterm premature rupture of membranes Adjusted for all pollutants lag 0 hrs: 1.04 (1.00, 1.07) lag 1 hr: 1.04 (1.00, 1.07) lag 2 hrs: 1.03 (1.00, 1.07) lag 3 hrs: 1.03 (1.00, 1.07) lag 4 hrs: 1.03 (1.00, 1.06)
Long Term Exposure			
Brauer et al. (2008) Vancouver, British Columbia, Canada 1999 – 2002 Cohort	N = 70,249	Inverse distance weighing (IDW), 3 closest monitors within 50km Monthly 5.1 Land use regression (LUR) Monthly 4.0	Preterm births (PTB) < 37 weeks EP: 1.34 (1.05, 1.69) Preterm births (PTB) < 30 weeks IDW: EP: 1.84 (0.66, 5.19) LUR: EP: 1.40 (0.90, 2.10)
†Chang et al. (2013) Mecklenburg County, North Carolina 2001 – 2005 Time-to-event	N = 55,647	Model, EPA's monitor corrected CMAQ Mean: 15.5	Preterm birth Cumulative pregnancy: 1.27 (1.07, 1.49) 4 week lag: 1.03 (0.96, 1.10)
†Chang et al. (2015) Atlanta, GA, U.S. 1999 – 2005 Time-to-event	N = 3,014,704	Monitor Means: 17.1 – 17.4	Reported as figures
†Darrow et al. (2009) Atlanta, GA, U.S. 1994 – 2004 Time-series	N = 1994 days, 476,789 births	Monitors, daily population weighted spatial averages from 11 monitors Means: 16.4 – 16.5	Preterm birth (RR) M1: 1.00 (0.98, 1.03) 6 week lag: 0.99 (0.95, 1.02) Within 4 miles of monitor M1: 0.99 (0.93, 1.05) 6 week lag: 1.05 (0.96, 1.16)
†Fleischer et al. (2014) Africa, Latin America, Asia 2001 - 2006 Survey	N = 22 counties, >290,000 women	Satellite derived estimates Means: 1.4 – 98.1	Preterm birth 2001-2006 avg: 0.96 (0.90, 1.02)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Gehring et al. (2011) The Netherlands 1996 – 1997 Cohort	N = 677,057	Land use regression Means: 19.1 – 21.3	Preterm birth EP: 1.24 (0.82, 1.89) T1: 0.99 (0.83, 1.18) Last month: 1.06 (0.85, 1.33)
†Gehring et al. (2014) Vancouver, Canada 1999 – 2002 Cohort	N = 68,238	Land use regression Mean: 4.1	Moderately preterm birth (30-36 weeks) EP: 1.00 (0.90, 1.16) Very preterm birth (<30 weeks) EP: 1.40 (1.00, 2.01)
†Ha et al. (2014) Florida, U.S. 2004 – 2005 Cohort	N = 423,719	EPA's Hierarchical Bayesian Prediction Model Means: 9.7 – 10.2	Preterm birth T1: 1.06 (1.03, 1.08) T2: 1.25 (1.22, 1.28) T3: 1.05 (1.02, 1.07) EP: 1.14 (1.10, 1.18) Very preterm birth (<32 weeks) T1: 1.12 (1.05, 1.20) T2: 1.45 (1.37, 1.54) T3: 1.02 (0.95, 1.09) EP: 1.22 (1.12, 1.32)
†Hannam et al. (2014) Northwest England 2004 – 2008 Cohort	N =38,608	Spatio-temporal model Mean: 22.1	Preterm birth EP: 0.98 (0.85, 1.12)
†Hyder et al. (2014) Connecticut and Massachusetts, U.S. 2000 – 2006 Cohort	N = 834,332	Monitor Mean: 11.9 Satellite model 1 Mean: 11.4 Satellite model 2 Mean: 11.2 Exposure over entire pregnancy	Preterm birth Monitor: 1.00 (0.98, 1.04) Satellite 1: 0.96 (0.86, 1.04) Satellite 2: 1.00 (0.92, 1.08)
†Kloog et al. (2012) Massachusetts, U.S. 2000 – 2008 Cohort	N = 634, 244	Satellite based model, 10x10 km Mean: 9.6	Preterm birth EP: 1.03 (0.54, 0.63)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Lee et al. (2013) Pittsburgh, PA, U.S. 1997 - 2002 Cohort	N = 34,703	Space-time ordinary kriging from monitors, to zip code Mean: 15.6	Preterm birth T1: 1.13 (1.01, 1.26) Non-smokers T1: 1.14 (0.99, 1.30) Smokers T1: 1.05 (0.85, 1.31)
†Padula et al. (2014) San Joaquin Valley, CA, U.S. 2000 – 2006 Cohort	N = 263,204	monitors, inverse distance squared weighing, within 50km Mean: NR 4th quartile compare to 1st quartile PM exposure	PTB, 34-36 weeks, EP: 1.27 (1.23, 1.31) PTB, 32-33, EP: 1.56 (1.44, 1.68) PTB, 28-31, EP: 1.62 (1.45, 1.78) PTB, 24-27, EP: 1.96 (1.68, 2.30) PTB, 20-23, EP: 1.08 (0.85, 1.38) PTB, 34-36 weeks, T1: 1.03 (1.00, 1.06) PTB, 32-33, T1: 0.96 (0.89, 1.03) PTB, 28-31, T1: 0.94 (0.86, 1.04) PTB, 24-27, T1: 0.78 (0.66, 0.91) PTB, 20-23, T1: 0.64 (0.51, 0.81) PTB, 34-36 weeks, T2: 1.09 (1.05, 1.12) PTB, 32-33, T2: 1.21 (1.12, 1.30) PTB, 28-31, T2: 1.55 (1.41, 1.70) PTB, 24-27, T2: 2.14 (1.84, 2.50) PTB, 20-23, T2: 2.83 (2.29, 3.50) PTB, 34-36 weeks, T3: 0.96 (0.93, 1.00) PTB, 32-33, T3: 1.03 (0.96, 1.12) PTB, 28-31, T3: 1.34 (1.22, 1.48)
†Pereira et al. (2014a) Connecticut, U.S. 2000 – 2006 Longitudinal cohort	N =29,175 women	Monitor, nearest within 40km Means: 12.13 – 12.41	Preterm birth T1: 1.15 (1.04, 1.25) T2: 0.90 (0.82, 0.99) T3: 1.08 (1.00, 1.14) EP: 1.30 (1.00, 1.29) White women T1: 1.03 (0.92, 1.16) T2: 0.91 (0.80, 1.04) T3: 1.05 (0.96, 1.14) EP: 1.04 (0.76, 1.48) Black women T1: 1.25 (0.97, 1.59) T2: 0.90 (0.69, 1.15) T3: 1.15 (0.97, 1.35) EP: 2.03 (0.98, 4.24) Hispanic women T1: 1.38 (1.12, 1.69) T2: 0.79 (0.64, 0.97) T3: 1.17 (1.01, 1.35) EP: 1.79 (1.00, 3.24)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Pereira et al. (2014b) Perth, Australia 1997 – 2007 Longitudinal cohort	N = 39,189 women	Monitor, nearest within 40km Means: 8.51 – 8.56	Preterm birth EP: 0.95 (0.77, 1.22) T1: 1.00 (0.82, 1.22) T2: 1.00 (0.82, 1.22) T3: 0.90 (0.73, 1.10) Premature rupture of membranes EP: 1.10 (0.95, 1.28) T1: 1.00 (0.86, 1.16) T2: 1.16 (1.00, 1.34) T3: 1.10 (1.00, 1.28)
†Pereira et al. (2015) Rochester, NY, U.S. 2004 – 2012 Longitudinal cohort	N = 3,264 women	Monitor, nearest within 40km Mean: 9	Preterm birth EP: 2.19 (1.40, 3.44) T1: 1.69 (1.22, 2.29) T2: 1.54 (1.10, 2.10) T3: 1.34 (1.00, 1.84) Premature rupture of membranes EP: 1.00 (0.86, 1.22) T1: 0.95 (0.82, 1.10) T2: 0.95 (0.82, 1.16) T3: 0.95 (0.73, 1.22)
†Rudra et al. (2011) Washington, U.S. 1996 – 2006 Cohort	N = 3,509 women	Land use regression Mean: 10.8	Preterm birth Last 3 months: 0.74 (0.39, 1.48)
†Salihu et al. (2012) Hillsborough County, Florida, U.S. 2000 – 2007 Cohort	N = 103,961	Monitor Mean: 11.28	Preterm birth Exposed v. unexposed, EP: 1.03 (0.98, 1.07) Very preterm birth (<33 weeks) Exposed v. unexposed, EP: 1.05 (0.93, 1.18)
†Stieb et al. (2015) Canada 1999 – 2008 Cohort	N = 2,781,940	Land use regression based on monitor and satellite data to postal code Mean: 8.33 – 8.51	Preterm birth EP: 0.95 (0.92, 0.98)
†Trasande et al. (2013) United States 2000, 2003, 2006 Cross-sectional	N = 222,359	Monitors averaged within 10 miles Mean: 12.63	Preterm birth Month of birth: 0.86 (0.82, 0.90)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Warren et al. (2012) Texas, U.S. 2002 – 2004 Cohort	N = 32,170	Monitors, CMAQ model Mean: NR	Reported as figures
†Wilhelm et al. (2011) Los Angeles County, CA, U.S. 6/1/04 - 3/31/06 Case-control	N = 10,265 cases, 102,2650 controls	Southern California Air Quality Management District Multiple Air Toxics Exposure Study Monitors Mean: 18	Preterm birth EP: 1.28 (1.05, 1.54)
†Wu et al. (2009) LA and Orange Counties, CA, U.S. 1997 – 2006 Cohort	N = 1997 - 2006	CALINE4 line-source dispersion model Mean: 1.82	Preterm birth (<37 weeks) EP: 1.03 (1.01, 1.06) Moderate preterm birth (<35 weeks) EP: 1.07 (1.03, 1.12) Very preterm birth (<30 weeks) EP: 1.18 (1.10, 1.26)
†Wu et al. (2011) LA and Orange Counties, CA, U.S. 1997 – 2006 Cohort	N = 1997 - 2006	CALINE4 line-source dispersion model Mean: 1.8 Monitor Mean: 17.3	Preterm birth Monitor, LA, EP: 1.22 (0.73, 2.01) Monitor, Orange, EP: 1.54 (1.00, 2.49) CALINE4, LA, EP: 1.22 (1.00, 1.47) CALINE4, Orange, EP: 1.10 (0.86, 1.40) Very preterm birth (<30 weeks) Monitor, LA, EP: 1.16 (0.35, 3.71) Monitor, Orange, EP: 4.16 (0.95, 17.37) CALINE4, LA, EP: 2.19 (1.34, 3.57) CALINE4, Orange, EP: 2.10 (1.05, 4.32)
†Lavigne et al. (2016b) Ontario, Canada 2005 - 2012 Cohort	N = 818,400	Satellite based model, 1x1 km Mean: 9.2	Preterm birth EP: 1.10 (1.06, 1.15)
†Defranco et al. (2016) Ohio, U.S. 2007 – 2010 Cohort	N = 224,921	Monitor Mean: 12.93 – 13.19	Preterm birth >15µg v. <15µg EP: 1.19 (1.09, 1.30) T1: 1.02 (0.97, 1.07) T2: 0.96 (0.90, 1.01) T3: 1.28 (1.20, 1.37)
†Hao et al. (2016) Georgia, U.S. Jan 1 2002 - Feb 28 2006 Cohort	N = 511,658	Model, fused CMAQ Mean: 11.44	Preterm birth EP: 1.05 (1.01, 1.09) T1: 1.00 (0.99, 1.03) T2: 1.03 (1.01, 1.05) T3: 1.01 (0.99, 1.03)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Johnson et al. (2016) New York City, NY, U.S. 2008 – 2010 Cohort	N = 258,294	Combination of NYC community air survey (spatial) and regulatory monitors (temporal), within 300m Mean: 11	Preterm birth T1: 0.98 (0.95, 1.02) T2: 0.97 (0.94, 1.01) Spontaneous preterm birth T1: 0.99 (0.95, 1.04) T2: 0.99 (0.95, 1.04) Medically indicated preterm birth T1: 0.97 (0.92, 1.03) T2: 0.97 (0.92, 1.04)
Mendola et al. (2016a) United States 2002 – 2008 Cohort	N = 223,502 deliveries	Model, specialized CMAQ, bias corrected with monitor data Averaged over delivery hospital referral region Exposures lagged before hour of admission for delivery Means: 11.78 – 11.92	Preterm birth, no asthma 3 months preconception: 0.91 (0.86, 0.95) weeks 1-7: 1.04 (1.02, 1.06) weeks 8-14: 0.97 (0.95, 0.99) weeks 15-21: 0.97 (0.95, 0.99) weeks 22-28: 0.99 (0.97, 1.01) last 6 weeks: 0.92 (0.90, 0.94) EP: 1.01 (0.99, 1.03) Preterm birth, asthma 3 months preconception: 0.96 (0.83, 1.10) weeks 1-7: 1.07 (1.01, 1.13) weeks 8-14: 1.02 (0.96, 1.07) weeks 15-21: 0.98 (0.93, 1.04) weeks 22-28: 1.00 (0.94, 1.06) last 6 weeks: 0.99 (0.94, 1.05) EP: 1.05 (0.99, 1.12) Very preterm birth (<34 weeks), no asthma 3 months preconception: 0.79 (0.72, 0.86) weeks 1-7: 1.04 (0.99, 1.07) weeks 8-14: 0.97 (0.94, 1.01) weeks 15-21: 1.01 (0.97, 1.04) weeks 22-28: 0.93 (0.89, 0.96) last 6 weeks: 0.89 (0.87, 0.92) EP: 1.02 (0.98, 1.05) Very preterm birth (<34 weeks), asthma 3 months preconception: 0.79 (0.64, 0.96) weeks 1-7: 1.10 (0.99, 1.21) weeks 8-14: 1.02 (0.93, 1.12) weeks 15-21: 1.05 (0.95, 1.14) weeks 22-28: 0.99 (0.91, 1.09) last 6 weeks: 1.03 (0.94, 1.13) EP: 1.12 (1.01, 1.24)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Laurent et al. (2016) Los Angeles County, CA, U.S. 2001 – 2008 Nested case-control	N = 442,314	Empirical Bayesian kriging from monitors Mean: NR Exposures are length of case pregnancy	Preterm birth 1.10 (1.09, 1.11) Adjusted for O3 1.09 (1.08, 1.10) Adjusted for NO2 1.11 (1.09, 1.12)
†Qian et al. (2015) Wuhan, China 2011 – 2013 Cohort	N = 95,911	Monitor Means: 70.8 (14.4)	Preterm birth EP: 1.03 (1.02, 1.05) T2: 1.02 (1.02, 1.03) Adjusted for SO2 EP: 1.04 (1.02, 1.05) Adjusted for NO2 EP: 1.03 (1.02, 1.05) Adjusted for CO EP: 1.03 (1.01, 1.04) Adjusted for O3 EP: 1.03 (1.02, 1.04)
†Lavigne et al. (2016b) Ontario, Canada Jan 1 2005 - March 31 2012 Cohort	N = 818,400 singleton live births	Satellite based estimates, 1x1 km Means: 9.07 – 9.20	Reported as figure
†Wallace et al. (2016) United States 2002 – 2008 Cohort	N = 223,375	Model, specialized CMAQ, bias corrected with monitor data Averaged over delivery hospital referral region Exposures lagged before hour of admission for delivery Means: 11.78 – 11.92	Premature rupture of membranes Adjusted for all pollutants EP: 0.93 (0.94, 1.02) Preterm premature rupture of membranes Adjusted for all pollutants EP: 0.87 (0.72, 1.03)
†Dadvand et al. (2014a) Barcelona, Spain 2002 - 2005 Cohort	N = 5,555 singleton live births	Land use regression Mean: NR	Premature rupture of membranes EP: 1.08 (0.67, 1.74) last 3 months: 1.13 (0.76, 1.70)

†Studies published since the 2009 Integrated Science Assessment.
[a]All estimates reported per 5µg increase in $PM_{2.5}$ unless otherwise stated.
CI = confidence interval; CMAQ = community multiscale air quality modeling system; C-RP = C-reactive protein; EP = entire pregnancy; FR = fecundity ratio; IRR = incidence rate ratio; M1 = 1st month of pregnancy; M7 = 7th month of pregnancy; OR = odds ratio; RR = risk or rate ratio; T1 = 1st trimester of pregnancy; T2 = 2nd trimester of pregnancy; T3 = 3rd trimester of pregnancy.

Table S9-4. Summary of epidemiologic studies of exposure to PM2.5 and birth defects

Study	Outcomes Examined	Location (sample size)	Mean $PM_{2.5}$ (μg/m^3)	Exposure Assessment	Exposure Window
		Short-term exposure			
Stingone et al. (2014)	Cardiac defects	Arkansas, Iowa, Massachusetts, California, Georgia, New York, North Carolina, Texas, and Utah, U.S. (n= 79 - 1718 cases depending on defect)	Median: 11.6	Nearest monitor within 50 km	Weeks 2-8 of gestation
Zhu et al. (2015)	Oral cleft defects	United States (n = 188,102)	Median: 10.37 – 11.74	Bias corrected modeled concentrations (specialized CMAQ) for delivery hospital referral region	Weeks 1-10 of gestation
Warren et al. (2016)	Cardiac defects	Arkansas, Iowa, Massachusetts, California, Georgia, New York, North Carolina, Texas, and Utah, U.S. (n= 79 - 1718 cases depending on defect)	NR	CMAQ, downscaled model	Daily for weeks 2-8 of gestation
		Long-term exposure			
Agay-Shay et al. (2013)	Cardiac defects	Israel 135,527 births, 5,125 cases	26.1	Inverse distance weighing, 2 – 5 monitors	Weeks 3-8 of gestation
Marshall et al. (2010)	Oral cleft defects	New Jersey, U.S. 717 cases	13.4	Nearest monitor, within 40km	Weeks 3-8 of gestation

Study	Outcomes Examined	Location (sample size)	Mean $PM_{2.5}$ (µg/m^3)	Exposure Assessment	Exposure Window
Padula et al. (2013b)	Cardiac defects	California, U.S. 813 cases, 828 controls	Median: 14.82	Inverse distance weighing, 1 – 4 monitors	Months 1 and 2 of gestation
Padula et al. (2013a)	Neural tube defects, oral cleft defects, gastroschisis	California, U.S. 806 cases, 849 controls	Median: 14.82	Inverse distance weighing, 1 – 4 monitors	Months 1 and 2 of gestation
Padula et al. (2013c)	Other defects	California, U.S. 874 cases, 849 controls	Median: 14.82	Inverse distance weighing, 1 – 4 monitors	Months 1 and 2 of gestation
Schembari et al. (2014)	Non-chromosomal anomalies	Barcelona, Spain 2247 cases, 2991 controls	median: 16.6	Land use regression with temporal adjustment	Weeks 3-8 of gestation
Vinikoor-Imler et al. (2015)	Various	Texas, U.S.; 21,060 cases, 1,401,611 controls all Texas; 291 cases 521 controls NBDPS	8.2	CMAQ model	1st trimester
Vinikoor-Imler et al. (2013)	Various	North Carolina, U.S. 322,969 births	14.03	CMAQ model	Weeks 3-8 of gestation
Jurewicz et al. (2014)	Chromosomal disomies	Poland 212 infertile men	35.64	Nearest monitor	90 days before sampling
Salemi et al. (2015)	Various	Florida, U.S. 156-1653 cases depending on defect	NR	Inverse distance squared weighing, monitors within 50km and 3 days	Weeks 3-12 of gestation depending on defect
Girguis et al. (2016)	Cardiac, neural tube, and orofacial defects	Massachusetts, U.S. 2729 cardiac cases, 255 neural tube cases, 729 orofacial cases; 7816 controls	NR	Modeled from satellite, meteorological, and land use data	Weeks 3-7 of gestation

Study	Outcomes Examined	Location (sample size)	Mean $PM_{2.5}$ (µg/m^3)	Exposure Assessment	Exposure Window
Zhu et al. (2015)	Orofacial defects	United States 63 cleft palate cases, 159 cleft lip w/wo palate cases	Median: 10.37 - 11.74	Bias corrected modeled concentrations (specialized CMAQ) for delivery hospital referral region	3 months preconception, weeks 3-7 of gestation
Zhang et al. (2016)	Cardiac defects	Wuhan, China 105,988 births	65.61	Nearest monitor	Months 1 to 3 of gestation

CMAQ = community multi-scale air quality modeling system; km = kilometer; NR = not reported.

Table S9-5. Studies of fetal and infant mortality

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
Short Term Studies			
†Faiz et al. (2013) New Jersey, U.S. 1999 – 2004 Case-crossover	N = 689 infants	Monitor, within 10km Mean: 15	Lag 2: 1.03 (0.96, 1.10) Lag 2, adjusted for O3: 0.98 (0.90, 1.08) Lag 2, adjusted for SO2: 1.00 (0.93, 1.09) Lag 2, adjusted for CO: 1.04 (0.95, 1.14)
†Yorifuji et al. (2016) Tokyo, Japan 2002 – 2013 Case-crossover	N = 2086 infants	Monitor Median: 16.7	Lag 0 All infant mortality: 1.03 (1.00, 1.06) Neonatal: 1.01 (0.97, 1.05) Post-neonatal: 1.05 (1.01, 1.09) Cardiac: 0.96 (0.82, 1.12) Respiratory: 1.14 (1.00, 1.29) Perinatal circumstances: 1.00 (0.95, 1.06) Birth defects: 1.04 (0.99, 1.09) SIDS: 1.05 (0.94, 1.17)
†Arroyo et al. (2016) Madrid, Spain 2004-2009 Time-series	N = 314 weeks	Monitor Mean: 17.1	Late fetal death (within 1st 24 hrs of life) Week 31 (lag 6 weeks): 1.06 (1.05, 1.06)[b]
Long Term Studies			
†Enkhmaa et al. (2014) Ulaanbaatar, Mongolia 2009-2011	N = 1219	Monitor	Strong correlation coefficients between monthly PM2.5 and monthly counts of spontaneous abortion before 20 weeks of gestation (>0.8)
†Defranco et al. (2015) Ohio, U.S. 2006-2010 Cohort	N = 351,036 births	Monitor, within 10km Mean: 13.3	Stillbirth, >20 weeks T1, >17.2 v. <17.2 0.77 (0.58, 1.02) T2, >16.26 v. <16.26 0.80 (0.62, 1.04) T3, >16.22 v. <16.22 1.42 (1.06, 1.91) EP, >15.67 v. <15.67 1.21 (0.96, 1.53)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Faiz et al. (2012) New Jersey, U.S. 1998-2004 Cohort	N =756,562 births (5381 stillbirths)	Monitor, within 10km Means: 13.7-14.3	Stillbirth, >20 weeks EP: 1.09 (0.83, 1.43) T1: 1.19 (0.95, 1.48) T2: 1.18 (0.95, 1.46) T3: 1.10 (0.74, 1.63)
†Green et al. (2015) California, U.S. 1999-2009 Cohort	N = 13,999	Monitor, nearest to population weighted zipcode centroid within 20km Means: 15.20 - 15.45	Stillbirth, >20 weeks T1: 1.00 (0.98, 1.02) T2: 1.01 (0.99, 1.03) T3: 1.00 (0.98, 1.03) EP: 1.03 (0.99, 1.06) Adjusted for NO2 T1: 0.98 (0.95, 1.02) T2: 1.00 (0.96, 1.03) T3: 1.00 (0.96, 1.05) EP: 0.98 (0.93, 1.05) Adjusted for O3 T1: 1.00 (0.98, 1.02) T2: 1.00 (0.98, 1.02) T3: 1.00 (0.98, 1.03) EP: 1.02 (0.99, 1.06) By air basin: Sacramento valley: 1.16 (1.00, 1.35) San Diego county: 1.09 (0.90, 1.32) San Francisco Bay: 1.15 (0.97, 1.36) San Joaquin Valley: 1.07 (1.00, 1.15) South Central Coast: 1.09 (0.79, 1.51) South Coast: 1.04 (0.99, 1.09)

Study	Study Population	Exposure Assessment	Effect Estimates (95% CI)[a]
†Son et al. (2011) Seoul, South Korea 2004-2007 Survival cohort	N = 359,459 births (225 deaths)	Monitor Means: 30.4-30.6	All cause post-neonatal infant mortality Normal birth weight EP + life: 1.96 (1.37, 2.77) T1: 1.25 (1.06, 1.48) T2: 1.25 (0.94, 1.67) T3: 1.10 (0.83, 1.46) Low birth weight EP + life: 1.00 (0.18, 5.54) T1: 1.05 (0.48, 2.30) T2: 1.46 (0.47, 4.50) T3: 0.77 (0.30, 1.98) Respiratory (n=26) EP + life: 6.18 (1.44, 26.33) T1: 2.07 (1.23, 3.47) T2: 1.15 (0.46, 2.84) T3: 1.82 (0.69, 4.78) SIDS (n=22) EP + life: 1.74 (0.58, 5.33) T1: 1.23 (0.73, 2.09) T2: 0.83 (0.38, 1.84) T3: 0.70 (0.31, 1.61)
Woodruff et al. (2008) United States 1999-2002 Cohort	N = ~3.5 million births (6,639 deaths)	Monitors, county average Means: 14.5 – 14.9 Exposures over 1st 2 months of life	Post-neonatal infant mortality All-cause: 1.03 (0.99, 1.08) Respiratory 1.08 (0.97, 1.20) Adjusted for CO: 1.04 (0.92, 1.17) SIDS 1.01 (0.90, 1.14) Adjusted for CO 1.03 (0.91, 1.16) Ill-defined + SIDS 1.04 (0.98, 1.12) Other 1.02 (0.97, 1.08)

†Studies published since the 2009 Integrated Science Assessment.

[a]All estimates reported per 5µg increase in $PM_{2.5}$ unless otherwise stated.

CI = confidence interval; CMAQ = community multiscale air quality modeling system; C-RP = C-reactive protein; EP = entire pregnancy; FR = fecundity ratio; M1 = 1st month of pregnancy; IRR = incidence rate ratio; M7 = 7th month of pregnancy; OR = odds ratio; RR = risk or rate ratio; T1 = 1st trimester of pregnancy; T2 = 2nd trimester of pregnancy; T3 = 3rd trimester of pregnancy.

References

Agay-Shay, K; Friger, M; Linn, S; Peled, A; Amitai, Y; Peretz, C. (2013). Air pollution and congenital heart defects. Environ Res 124: 28-34. http://dx.doi.org/10.1016/j.envres.2013.03.005.

Arroyo, V; Díaz, J; Carmona, R; Ortiz, C; Linares, C. (2016). Impact of air pollution and temperature on adverse birth outcomes: Madrid, 2001-2009. Environ Pollut 218: 1154-1161. http://dx.doi.org/10.1016/j.envpol.2016.08.069.

Arroyo, V; Díaz, J; Ortiz, C; Carmona, R; Sáez, M; Linares, C. (2015). Short term effect of air pollution, noise and heat waves on preterm births in Madrid (Spain). Environ Res 145: 162-168. http://dx.doi.org/10.1016/j.envres.2015.11.034.

Beckerman, BS; Jerrett, M; Serre, M; Martin, RV; Lee, S; van Donkelaar, A; Ross, Z; Su, J; Burnett, RT. (2013). A hybrid approach to estimating national scale spatiotemporal variability of PM2.5 in the contiguous United States. Environ Sci Technol 47: 7233-7241. http://dx.doi.org/10.1021/es400039u.

Bell, ML; Belanger, K; Ebisu, K; Gent, JF; Lee, HJ; Koutrakis, P; Leaderer, BP. (2010). Prenatal exposure to fine particulate matter and birth weight: Variations by particulate constituents and sources. Epidemiology 21: 884-891. http://dx.doi.org/10.1097/EDE.0b013e3181f2f405.

Brauer, M; Lencar, C; Tamburic, L; Koehoorn, M; Demers, P; Karr, C. (2008). A cohort study of traffic-related air pollution impacts on birth outcomes. Environ Health Perspect 116: 680-686. http://dx.doi.org/10.1289/ehp.10952.

Brown, JM; Harris, G; Pantea, C; Hwang, SA; Talbot, TO. (2015). Linking air pollution data and adverse birth outcomes: Environmental public health tracking in New York State. J Public Health Manag Pract 21: S68-S74. http://dx.doi.org/10.1097/PHH.0000000000000171.

Cândido da Silva, AM; Moi, GP; Mattos, IE; Hacon, S. (2014). Low birth weight at term and the presence of fine particulate matter and carbon monoxide in the Brazilian Amazon: a population-based retrospective cohort study. BMC Pregnancy Childbirth 14: 309. http://dx.doi.org/10.1186/1471-2393-14-309.

Chang, HH; Reich, BJ; Miranda, ML. (2013). A spatial time-to-event approach for estimating associations between air pollution and preterm birth. J R Stat Soc Ser C Appl Stat 62: 167-179. http://dx.doi.org/10.1111/j.1467-9876.2012.01056.x.

Chang, HH; Warren, JL; Darrow, LA; Reich, BJ; Waller, LA. (2015). Assessment of critical exposure and outcome windows in time-to-event analysis with application to air pollution and preterm birth study. Biostatistics 16: 509-521. http://dx.doi.org/10.1093/biostatistics/kxu060.

Dadvand, P; Basagaña, X; Figueras, F; Martinez, D; Beelen, R; Cirach, M; de Nazelle, A; Hoek, G; Ostro, B; Nieuwenhuijsen, MJ. (2014a). Air pollution and preterm premature rupture of membranes: a spatiotemporal analysis. Am J Epidemiol 179: 200-207. http://dx.doi.org/10.1093/aje/kwt240.

Dadvand, P; Figueras, F; Basagaña, X; Beelen, R; Martinez, D; Cirach, M; Schembari, A; Hoek, G; Brunekreef, B; Nieuwenhuijsen, MJ. (2013a). Ambient air pollution and preeclampsia: A spatiotemporal analysis. Environ Health Perspect 121: 1365-1371. http://dx.doi.org/10.1289/ehp.1206430.

Dadvand, P; Ostro, B; Amato, F; Figueras, F; Minguillon, MC; Martinez, D; Basagana, X; Querol, X; Nieuwenhuijsen, M. (2014b). Particulate air pollution and preeclampsia: a source-based analysis. Occup Environ Med 71: 570-577. http://dx.doi.org/10.1136/oemed-2013-101693.

Dadvand, P; Ostro, B; Figueras, F; Foraster, M; Basagaña, X; Valentín, A; Martinez, D; Beelen, R; Cirach, M; Hoek, G; Jerrett, M; Brunekreef, B; Nieuwenhuijsen, MJ. (2014c).

Residential proximity to major roads and term low birth weight: The roles of air pollution, heat, noise, and road-adjacent trees. Epidemiology 25: 518-525. http://dx.doi.org/10.1097/EDE.0000000000000107.
Dadvand, P; Parker, J; Bell, ML; Bonzini, M; Brauer, M; Darrow, L; Gehring, U; Glinianaia, SV; Gouveia, N; Ha, EH; Leem, JH; van den Hooven, EH; Jalaludin, B; Jesdale, BM; Lepeule, J; Morello-Frosch, R; Morgan, GG; Pesatori, AC; Pierik, FH; Pless-Mulloli, T; Rich, DQ; Sathyanarayana, S; Seo, J; Slama, R; Strickland, M; Tamburic, L; Wartenberg, D; Nieuwenhuijsen, MJ; Woodruff, TJ. (2013b). Maternal exposure to particulate air pollution and term birth weight: a multi-country evaluation of effect and heterogeneity. Environ Health Perspect 121: 267-373. http://dx.doi.org/10.1289/ehp.1205575.
Darrow, LA; Klein, M; Flanders, WD; Waller, LA; Correa, A; Marcus, M; Mulholland, JA; Russell, AG; Tolbert, PE. (2009). Ambient air pollution and preterm birth: A time-series analysis. Epidemiology 20: 689-698. http://dx.doi.org/10.1097/EDE.0b013e3181a7128f.
Darrow, LA; Klein, M; Strickland, MJ; Mulholland, JA; Tolbert, PE. (2011). Ambient air pollution and birth weight in full-term infants in Atlanta, 1994-2004. Environ Health Perspect 119: 731-737. http://dx.doi.org/10.1289/ehp.1002785.
Defranco, E; Hall, E; Hossain, M; Chen, A; Haynes, EN; Jones, D; Ren, S; Lu, L; Muglia, L. (2015). Air pollution and stillbirth risk: exposure to airborne particulate matter during pregnancy is associated with fetal death. PLoS ONE 10: e0120594. http://dx.doi.org/10.1371/journal.pone.0120594.
Defranco, E; Moravec, W; Xu, F; Hall, E; Hossain, M; Haynes, EN; Muglia, L; Chen, A. (2016). Exposure to airborne particulate matter during pregnancy is associated with preterm birth: a population-based cohort study. Environ Health 15: 6. http://dx.doi.org/10.1186/s12940-016-0094-3.
Ebisu, K; Bell, ML. (2012). Airborne PM2.5 chemical components and low birth weight in the Northeastern and Mid-Atlantic regions of the United States. Environ Health Perspect 120: 1746-1752. http://dx.doi.org/10.1289/ehp.1104763.
Enkhmaa, D; Warburton, N; Javzandulam, B; Uyanga, J; Khishigsuren, Y; Lodoysamba, S; Enkhtur, S; Warburton, D. (2014). Seasonal ambient air pollution correlates strongly with spontaneous abortion in Mongolia. BMC Pregnancy Childbirth 14: 146. http://dx.doi.org/10.1186/1471-2393-14-146.
Erickson, AC; Ostry, A; Chan, LHM; Arbour, L. (2016). The reduction of birth weight by fine particulate matter and its modification by maternal and neighbourhood-level factors: a multilevel analysis in British Columbia, Canada. Environ Health 15: 51. http://dx.doi.org/10.1186/s12940-016-0133-0.
Faiz, AS; Rhoads, GG; Demissie, K; Kruse, L; Lin, Y; Rich, DQ. (2012). Ambient air pollution and the risk of stillbirth. Am J Epidemiol 176: 308-316. http://dx.doi.org/10.1093/aje/kws029.
Faiz, AS; Rhoads, GG; Demissie, K; Lin, Y; Kruse, L; Rich, DQ. (2013). Does ambient air pollution trigger stillbirth? Epidemiology 24: 538-544. http://dx.doi.org/10.1097/EDE.0b013e3182949ce5.
Fleisch, AF; Gold, DR; Rifas-Shiman, SL; Koutrakis, P; Schwartz, JD; Kloog, I; Melly, S; Coull, BA; Zanobetti, A; Gillman, MW; Oken, E. (2014). Air pollution exposure and abnormal glucose tolerance during pregnancy: the project Viva cohort. Environ Health Perspect 122: 378-383. http://dx.doi.org/10.1289/ehp.1307065.
Fleisch, AF; Kloog, I; Luttmann-Gibson, H; Gold, DR; Oken, E; Schwartz, JD. (2016). Air pollution exposure and gestational diabetes mellitus among pregnant women in Massachusetts: a cohort study. Environ Health 15: 40. http://dx.doi.org/10.1186/s12940-016-0121-4.

Fleisch, AF; Rifas-Shiman, SL; Koutrakis, P; Schwartz, JD; Kloog, I; Melly, S; Coull, BA; Zanobetti, A; Gillman, MW; Gold, DR; Oken, E. (2015). Prenatal exposure to traffic pollution: associations with reduced fetal growth and rapid infant weight gain. Epidemiology 26: 43-50. http://dx.doi.org/10.1097/EDE.0000000000000203.

Fleischer. (2014). Erratum: Outdoor air pollution, preterm birth, and low birth weight: analysis of the world health organization global survey on maternal and perinatal health (EHP vol 122, pg 425, 2014). Environ Health Perspect 122: A151-A151. http://dx.doi.org/10.1289/ehp.122-A151.

Fleischer, NL; Merialdi, M; van Donkelaar, A; Vadillo-Ortega, F; Martin, RV; Betran, A; Souza, JP; O'Neill, MS. (2014). Outdoor Air Pollution, Preterm Birth, And Low Birth Weight: Analysis Of The World Health Organization Global Survey On Maternal And Perinatal Health. Environ Health Perspect 122: 425-430. http://dx.doi.org/10.1289/ehp.1306837.

Geer, LA; Weedon, J; Bell, ML. (2012). Ambient air pollution and term birth weight in Texas from 1998 to 2004. J Air Waste Manag Assoc 62: 1285-1295. http://dx.doi.org/10.1080/10962247.2012.707632.

Gehring, U; Tamburic, L; Sbihi, H; Davies, HW; Brauer, M. (2014). Impact of noise and air pollution on pregnancy outcomes. Epidemiology 25: 351-358. http://dx.doi.org/10.1097/EDE.0000000000000073.

Gehring, U; Wijga, AH; Fischer, P; de Jongste, JC; Kerkhof, M; Koppelman, GH; Smit, HA; Brunekreef, B. (2011). Traffic-related air pollution, preterm birth and term birth weight in the PIAMA birth cohort study. Environ Res 111: 125-135. http://dx.doi.org/10.1016/j.envres.2010.10.004.

Girguis, MS; Strickland, MJ; Hu, X; Liu, Y; Bartell, SM; Vieira, VM. (2016). Maternal exposure to traffic-related air pollution and birth defects in Massachusetts. Environ Res 146: 1-9. http://dx.doi.org/10.1016/j.envres.2015.12.010.

Gray, SC; Edwards, SE; Miranda, ML. (2010). Assessing exposure metrics for PM and birth weight models. J Expo Sci Environ Epidemiol 20: 469-477. http://dx.doi.org/10.1038/jes.2009.52.

Gray, SC; Edwards, SE; Schultz, BD; Miranda, ML. (2014). Assessing the impact of race, social factors and air pollution on birth outcomes: a population-based study. Environ Health 13: 4. http://dx.doi.org/10.1186/1476-069X-13-4.

Green, R; Sarovar, V; Malig, B; Basu, R. (2015). Association of stillbirth with ambient air pollution in a California cohort study. Am J Epidemiol 181: 874-882. http://dx.doi.org/10.1093/aje/kwu460.

Ha, S; Hu, H; Roussos-Ross, D; Haidong, K; Roth, J; Xu, X. (2014). The effects of air pollution on adverse birth outcomes. Environ Res 134C: 198-204. http://dx.doi.org/10.1016/j.envres.2014.08.002.

Ha, S; Zhu, Y; Liu, D; Sherman, S; Mendola, P. (2017). Ambient temperature and air quality in relation to small for gestational age and term low birthweight. Environ Res 155: 394-400. http://dx.doi.org/10.1016/j.envres.2017.02.021.

Hammoud, A; Carrell, DT; Gibson, M; Sanderson, M; Parker-Jones, K; Matthew Peterson, C. (2009). Decreased sperm motility is associated with air pollution in Salt Lake City. Fertil Steril TBD: TBD. http://dx.doi.org/10.1016/j.fertnstert.2008.12.089.

Hannam, K; Mcnamee, R; Baker, P; Sibley, C; Agius, R. (2014). Air pollution exposure and adverse pregnancy outcomes in a large UK birth cohort: use of a novel spatio-temporal modelling technique. Scand J Work Environ Health 40: 518-530. http://dx.doi.org/10.5271/sjweh.3423.

Hansen, C; Luben, TJ; Sacks, JD; Olshan, A; Jeffay, S; Strader, L; Perreault, SD. (2010). The effect of ambient air pollution on sperm quality. Environ Health Perspect 118: 203-209. http://dx.doi.org/10.1289/ehp.0901022.

Hao, H; Chang, HH; Holmes, HA; Mulholland, JA; Klein, M; Darrow, LA; Strickland, MJ. (2016). Air pollution and preterm birth in the U.S. state of Georgia (2002-2006): Associations with concentrations of 11 ambient air pollutants estimated by combining community multiscale air quality model (CMAQ) simulations with stationary monitor measurements. Environ Health Perspect 124: 875-880. http://dx.doi.org/10.1289/ehp.1409651.

Harris, G; Thompson, WD; Fitzgerald, E; Wartenberg, D. (2014). The association of PM2.5 with full term low birth weight at different spatial scales. Environ Res 134C: 427-434. http://dx.doi.org/10.1016/j.envres.2014.05.034.

Herr, CE; Dostal, M; Ghosh, R; Ashwood, P; Lipsett, M; Pinkerton, KE; Sram, R; Hertz-Picciotto, I. (2010). Air pollution exposure during critical time periods in gestation and alterations in cord blood lymphocyte distribution: A cohort of livebirths. Environ Health 9: 46. http://dx.doi.org/10.1186/1476-069X-9-46.

Hu, H; Ha, S; Henderson, BH; Warner, TD; Roth, J; Kan, H; Xu, X. (2015). Association of atmospheric particulate matter and ozone with gestational diabetes mellitus. Environ Health Perspect 123: 853-859. http://dx.doi.org/10.1289/ehp.1408456.

Hyder, A; Lee, H; Ebisu, K; Koutrakis, P; Belanger, K; Bell, M. (2014). PM2.5 exposure and birth outcomes use of satellite- and monitor-based data. Epidemiology 25: 58-67. http://dx.doi.org/10.1097/EDE.0000000000000027.

Janssen, BG; Saenen, ND; Roels, HA; Madhloum, N; Gyselaers, W; Lefebvre, W; Penders, J; Vanpoucke, C; Vrijens, K; Nawrot, TS. (2016). Fetal thyroid function, birth weight, and in utero exposure to fine particle air pollution: A birth cohort study. Environ Health Perspect 125: 699-705. http://dx.doi.org/10.1289/EHP508.

Jedrychowski, W; Perera, F; Mrozek-Budzyn, D; Flak, E; Mroz, E; Sochacka-Tatara, E; Jacek, R; Kaim, I; Skolicki, Z; Spengler, JD. (2010). Higher fish consumption in pregnancy may confer protection against the harmful effect of prenatal exposure to fine particulate matter. Ann Nutr Metab 56: 119-126. http://dx.doi.org/10.1159/000275918.

Jedrychowski, WA; Majewska, R; Spengler, JD; Camann, D; Roen, EL; Perera, FP. (2017). Prenatal exposure to fine particles and polycyclic aromatic hydrocarbons and birth outcomes: a two-pollutant approach. Int Arch Occup Environ Health 90: 255-264. http://dx.doi.org/10.1007/s00420-016-1192-9.

Jedrychowski, WA; Perera, FP; Maugeri, U; Spengler, J; Mroz, E; Flak, E; Stigter, L; Majewska, R; Kaim, I; Sowa, A; Jacek, R. (2012). Prohypertensive effect of gestational personal exposure to fine particulate matter. prospective cohort study in non-smoking and non-obese pregnant women. Cardiovasc Toxicol 12: 216-225. http://dx.doi.org/10.1007/s12012-012-9157-z.

Johnson, S; Bobb, JF; Ito, K; Savitz, DA; Elston, B; Shmool, JL; Dominici, F; Ross, Z; Clougherty, JE; Matte, T. (2016). Ambient fine particulate matter, nitrogen dioxide, and preterm birth in New York City. Environ Health Perspect 124: 1283-1290. http://dx.doi.org/10.1289/ehp.1510266.

Jurewicz, J; Radwan, M; Sobala, W; Polańska, K; Radwan, P; Jakubowski, L; Ulańska, A; Hanke, W. (2014). The relationship between exposure to air pollution and sperm disomy. Environ Mol Mutagen 56: 50-59. http://dx.doi.org/10.1002/em.21883.

Keller, JP; Chang, HH; Strickland, MJ; Szpiro, AA. (2017). Measurement error correction for predicted spatiotemporal air pollution exposures. Epidemiology 28: 338-345. http://dx.doi.org/10.1097/EDE.0000000000000623.

Kloog, I; Koutrakis, P; Coull, BA; Lee, HJ; Schwartz, J. (2011). Assessing temporally and spatially resolved PM2.5 exposures for epidemiological studies using satellite aerosol optical depth measurements. Atmos Environ 45: 6267-6275. http://dx.doi.org/10.1016/j.atmosenv.2011.08.066.

Kloog, I; Melly, SJ; Ridgway, WL; Coull, BA; Schwartz, J. (2012). Using new satellite based exposure methods to study the association between pregnancy PM 2.5 exposure,

premature birth and birth weight in Massachusetts. Environ Health 11: 40. http://dx.doi.org/10.1186/1476-069X-11-40.
Lakshmanan, A; Chiu, YH; Coull, BA; Just, AC; Maxwell, SL; Schwartz, J; Gryparis, A; Kloog, I; Wright, RJ; Wright, RO. (2015). Associations between prenatal traffic-related air pollution exposure and birth weight: Modification by sex and maternal pre-pregnancy body mass index. Environ Res 137: 268-277. http://dx.doi.org/10.1016/j.envres.2014.10.035.
Laurent, O; Hu, J; Li, L; Cockburn, M; Escobedo, L; Kleeman, MJ; Wu, J. (2014). Sources and contents of air pollution affecting term low birth weight in Los Angeles County, California, 20012008. Environ Res 134: 488-495. http://dx.doi.org/10.1016/j.envres.2014.05.003.
Laurent, O; Hu, J; Li, L; Kleeman, MJ; Bartell, SM; Cockburn, M; Escobedo, L; Wu, J. (2016). A statewide nested case-control study of preterm birth and air pollution by source and composition: California, 2001-2008. Environ Health Perspect 124: 1479-1486. http://dx.doi.org/10.1289/ehp.1510133.
Laurent, O; Wu, J; Li, L; Chung, J; Bartell, S. (2013). Investigating the association between birth weight and complementary air pollution metrics: a cohort study. Environ Health 12: 18. http://dx.doi.org/10.1186/1476-069X-12-18.
Lavigne, E; Ashley-Martin, J; Dodds, L; Arbuckle, TE; Hystad, P; Johnson, M; Crouse, DL; Ettinger, AS; Shapiro, GD; Fisher, M; Morisset, AS; Taback, S; Bouchard, MF; Sun, L; Monnier, P; Dallaire, R; Fraser, WD. (2016a). Air pollution exposure during pregnancy and fetal markers of metabolic function: the MIREC Study. Am J Epidemiol 183: 842-851. http://dx.doi.org/10.1093/aje/kwv256.
Lavigne, E; Yasseen, AS; Stieb, DM; Hystad, P; van Donkelaar, A; Martin, RV; Brook, JR; Crouse, DL; Burnett, RT; Chen, H; Weichenthal, S; Johnson, M; Villeneuve, PJ; Walker, M. (2016b). Ambient air pollution and adverse birth outcomes: Differences by maternal comorbidities. Environ Res 148: 457-466. http://dx.doi.org/10.1016/j.envres.2016.04.026.
Lee, H; Coull, BA; Bell, ML; Koutrakis, P. (2012a). Use of satellite-based aerosol optical depth and spatial clustering to predict ambient PM2.5 concentrations. Environ Res 118: 8-15. http://dx.doi.org/10.1016/j.envres.2012.06.011.
Lee, HJ; Liu, Y; Coull, BA; Schwartz, J; Koutrakis, P. (2011a). A novel calibration approach of MODIS AOD data to predict PM2.5 concentrations. Atmos Chem Phys Discuss 11: 97699795. http://dx.doi.org/10.5194/acpd-11-9769-2011.
Lee, PC; Roberts, JM; Catov, JM; Talbott, EO; Ritz, B. (2013). First Trimester Exposure To Ambient Air Pollution, Pregnancy Complications And Adverse Birth Outcomes In Allegheny County, PA. Matern Child Health J 17: 545-555. http://dx.doi.org/10.1007/s10995-012-1028-5.
Lee, PC; Talbott, EO; Roberts, JM; Catov, JM; Bilonick, RA; Stone, RA; Sharma, RK; Ritz, B. (2012b). Ambient air pollution exposure and blood pressure changes during pregnancy. Environ Res 117: 46-53. http://dx.doi.org/10.1016/j.envres.2012.05.011.
Lee, PC; Talbott, EO; Roberts, JM; Catov, JM; Sharma, RK; Ritz, B. (2011b). Particulate air pollution exposure and C-reactive protein during early pregnancy. Epidemiology 22: 524-531. http://dx.doi.org/10.1097/EDE.0b013e31821c6c58.
Madsen, C; Gehring, U; Walker, SE; Brunekreef, B; Stigum, H; Naess, O; Nafstad, P. (2010). Ambient air pollution exposure, residential mobility and term birth weight in Oslo, Norway. Environ Res 110: 363-371. http://dx.doi.org/10.1016/j.envres.2010.02.005.
Mahalingaiah, S; Hart, JE; Laden, F; Aschengrau, A; Missmer, SA. (2014). Air pollution exposures during adulthood and risk of endometriosis in the Nurses' Health Study II. Environ Health Perspect 122: 58-64. http://dx.doi.org/10.1289/ehp.1306627.
Mahalingaiah, S; Hart, JE; Laden, F; Farland, LV; Hewlett, MM; Chavarro, J; Aschengrau, A; Missmer, SA. (2016). Adult air pollution exposure and risk of infertility in the Nurses' Health Study II. Hum Reprod 31: 638-647. http://dx.doi.org/10.1093/humrep/dev330.

Männistö, T; Mendola, P; Grantz, KL; Leishear, K; Sundaram, R; Sherman, S; Ying, Q; Liu, D. (2015). Acute and recent air pollution exposure and cardiovascular events at labour and delivery. Heart 101: 1491-1498. http://dx.doi.org/10.1136/heartjnl-2014-307366.

Männistö, T; Mendola, P; Liu, D; Leishear, K; Sherman, S; Laughon, SK. (2014). Acute air pollution exposure and blood pressure at delivery among women with and without hypertension. Am J Hypertens 28: 58-72. http://dx.doi.org/10.1093/ajh/hpu077.

Marshall, E; Harris, G; Wartenberg, D. (2010). Oral cleft defects and maternal exposure to ambient air pollutants in New Jersey. Birth Defects Res A Clin Mol Teratol 88: 205-215. http://dx.doi.org/10.1002/bdra.20650.

Mendola, P; Wallace, M; Hwang, BS; Liu, D; Robledo, C; Männistö, T; Sundaram, R; Sherman, S; Ying, Q; Grantz, KL. (2016a). Preterm birth and air pollution: Critical windows of exposure for women with asthma. J Allergy Clin Immunol 138: 432-440.e435. http://dx.doi.org/10.1016/j.jaci.2015.12.1309.

Mendola, P; Wallace, M; Liu, D; Robledo, C; Männistö, T; Grantz, KL. (2016b). Air pollution exposure and preeclampsia among US women with and without asthma. Environ Res 148: 248-255. http://dx.doi.org/10.1016/j.envres.2016.04.004.

Mobasher, Z; Salam, MT; Goodwin, TM; Lurmann, F; Ingles, SA; Wilson, ML. (2013). Associations between ambient air pollution and hypertensive disorders of pregnancy. Environ Res 123: 9-16. http://dx.doi.org/10.1016/j.envres.2013.01.006.

Morello-Frosch, R; Jesdale, BM; Sadd, JL; Pastor, M. (2010). Ambient air pollution exposure and full-term birth weight in California. Environ Health 9: 44. http://dx.doi.org/10.1186/1476-069X-9-44.

Nachman, RM; Mao, G; Zhang, X; Hong, X; Chen, Z; Soria, CS; He, H; Wang, G; Caruso, D; Pearson, C; Biswal, S; Zuckerman, B; Wills-Karp, M; Wang, X. (2016). Intrauterine inflammation and maternal exposure to ambient PM2.5 during preconception and specific periods of pregnancy: the Boston Birth Cohort. Environ Health Perspect 124: 1608-1615. http://dx.doi.org/10.1289/EHP243.

Nieuwenhuijsen, MJ; Basagaña, X; Dadvand, P; Martinez, D; Cirach, M; Beelen, R; Jacquemin, B. (2014). Air pollution and human fertility rates. Environ Int 70: 9-14. http://dx.doi.org/10.1016/j.envint.2014.05.005.

Padula, AM; Mortimer, KM; Tager, IB; Hammond, SK; Lurmann, FW; Yang, W; Stevenson, DK; Shaw, GM. (2014). Traffic-related air pollution and risk of preterm birth in the San Joaquin Valley of California. Ann Epidemiol 24: 888-895.e884. http://dx.doi.org/10.1016/j.annepidem.2014.10.004.

Padula, AM; Tager, IB; Carmichael, SL; Hammond, SK; Lurmann, F; Shaw, GM. (2013a). The association of ambient air pollution and traffic exposures with selected congenital anomalies in the San Joaquin Valley of California. Am J Epidemiol 177: 1074-1085. http://dx.doi.org/10.1093/aje/kws367.

Padula, AM; Tager, IB; Carmichael, SL; Hammond, SK; Yang, W; Lurmann, F; Shaw, GM. (2013b). Ambient air pollution and traffic exposures and congenital heart defects in the San Joaquin Valley of California. Paediatr Perinat Epidemiol 27: 329-339. http://dx.doi.org/10.1111/ppe.12055.

Padula, AM; Tager, IB; Carmichael, SL; Hammond, SK; Yang, W; Lurmann, FW; Shaw, GM. (2013c). Traffic-related air pollution and selected birth defects in the San Joaquin Valley of California. Birth Defects Res A Clin Mol Teratol 97: 730-735. http://dx.doi.org/10.1002/bdra.23175.

Parker, JD; Woodruff, TJ. (2008). Influences of study design and location on the relationship between particulate matter air pollution and birthweight. Paediatr Perinat Epidemiol 22: 214-227. http://dx.doi.org/10.1111/j.1365-3016.2008.00931.x.

Pedersen, M; Giorgis-Allemand, L; Bernard, C; Aguilera, I; Andersen, AM; Ballester, F; Beelen, RM; Chatzi, L; Cirach, M; Danileviciute, A; Dedele, A; van Eijsden, M; Estarlich, M;

Fernández-Somoano, A; Fernández, MF; Forastiere, F; Gehring, U; Grazuleviciene, R; Gruzieva, O; Heude, B; Hoek, G; de Hoogh, K; van Den Hooven, EH; Håberg, SE; Jaddoe, VW; Klümper, C; Korek, M; Krämer, U; Lerchundi, A; Lepeule, J; Nafstad, P; Nystad, W; Patelarou, E; Porta, D; Postma, D; Raaschou-Nielsen, O; Rudnai, P; Sunyer, J; Stephanou, E; Sørensen, M; Thiering, E; Tuffnell, D; Varró, MJ; Vrijkotte, TG; Wijga, A; Wilhelm, M; Wright, J; Nieuwenhuijsen, MJ; Pershagen, G; Brunekreef, B; Kogevinas, M; Slama, R. (2013). Ambient air pollution and low birthweight: a European cohort study (ESCAPE). Lancet Respir Med 1: 695-704. http://dx.doi.org/10.1016/S2213-2600(13)70192-9.

Pereira, G; Belanger, K; Ebisu, K; Bell, ML. (2014a). Fine Particulate Matter And Risk Of Preterm Birth In Connecticut In 2000-2006: A Longitudinal Study. Am J Epidemiol 179: 67-74. http://dx.doi.org/10.1093/aje/kwt216.

Pereira, G; Bell, ML; Belanger, K; de Klerk, N. (2014b). Fine particulate matter and risk of preterm birth and pre-labor rupture of membranes in Perth, Western Australia 1997-2007: a longitudinal study. Environ Int 73: 143-149. http://dx.doi.org/10.1016/j.envint.2014.07.014.

Pereira, G; Evans, KA; Rich, DQ; Bracken, MB; Bell, ML. (2015). Fine particulates, preterm birth, and membrane rupture in Rochester, NY. Epidemiology 27: 66-73. http://dx.doi.org/10.1097/EDE.0000000000000366.

Qian, Z; Liang, S; Yang, S; Trevathan, E; Huang, Z; Yang, R; Wang, J; Hu, K; Zhang, Y; Vaughn, M; Shen, L; Liu, W; Li, P; Ward, P; Yang, L; Zhang, W; Chen, W; Dong, G; Zheng, T; Xu, S; Zhang, B. (2015). Ambient air pollution and preterm birth: A prospective birth cohort study in Wuhan, China. Int J Hyg Environ Health 219: 195-203. http://dx.doi.org/10.1016/j.ijheh.2015.11.003.

Radwan, M; Jurewicz, J; Polańska, K; Sobala, W; Radwan, P; Bochenek, M; Hanke, W. (2015). Exposure to ambient air pollution-does it affect semen quality and the level of reproductive hormones? Ann Hum Biol 43: 50-56. http://dx.doi.org/10.3109/03014460.2015.1013986.

Rappazzo, KM; Daniels, JL; Messer, LC; Poole, C; Lobdell, DT. (2014). Exposure To Fine Particulate Matter During Pregnancy And Risk Of Preterm Birth Among Women In New Jersey, Ohio, And Pennsylvania, 2000-2005. Environ Health Perspect 122: 992-997. http://dx.doi.org/10.1289/ehp.1307456.

Rich, DQ; Demissie, K; Lu, SE; Kamat, L; Wartenberg, D; Rhoads, GG. (2009). Ambient air pollutant concentrations during pregnancy and the risk of fetal growth restriction. J Epidemiol Community Health 63: 488-496. http://dx.doi.org/10.1136/jech.2008.082792.

Robledo, CA; Mendola, P; Yeung, E; Männistö, T; Sundaram, R; Liu, D; Ying, Q; Sherman, S; Grantz, KL. (2015). Preconception and early pregnancy air pollution exposures and risk of gestational diabetes mellitus. Environ Res 137: 316-322. http://dx.doi.org/10.1016/j.envres.2014.12.020.

Rudra, CB; Williams, MA; Sheppard, L; Koenig, JQ; Schiff, MA. (2011). Ambient carbon monoxide and fine particulate matter in relation to preeclampsia and preterm delivery in western Washington state. Environ Health Perspect 119: 886-892. http://dx.doi.org/10.1289/ehp.1002947.

Saenen, ND; Plusquin, M; Bijnens, E; Janssen, BG; Gyselaers, W; Cox, B; Fierens, F; Molenberghs, G; Penders, J; Vrijens, K; De Boever, P; Nawrot, T. (2015). In utero fine particle air pollution and placental expression of genes in the brain-derived neurotrophic factor signaling pathway: An ENVIRONAGE birth cohort study. Environ Health Perspect 123: 834-840. http://dx.doi.org/10.1289/ehp.1408549.

Saenen, ND; Vrijens, K; Janssen, BG; Madhloum, N; Peusens, M; Gyselaers, W; Vanpoucke, C; Lefebvre, W; Roels, HA; Nawrot, TS. (2016). Placental nitrosative stress and

exposure to ambient air pollution during gestation: A population study. Am J Epidemiol 184: 442-449. http://dx.doi.org/10.1093/aje/kww007.
Salemi, JL; Tanner, JP; Stuart, AL; Jordan, MM; Duclos, C; Cavicchia, P; Correia, J; Watkins, SM; Kirby, RS. (2015). Associations between exposure to ambient benzene and PM2.5 during pregnancy and the risk of selected birth defects in offspring [Abstract]. Birth Defects Res A Clin Mol Teratol 103: 427-427. http://dx.doi.org/10.1002/bdra.23387/pdf.
Salihu, HM; Ghaji, N; Mbah, AK; Alio, AP; August, EM; Boubakari, I. (2012). Particulate pollutants and racial/ethnic disparity in feto-infant morbidity outcomes. Matern Child Health J 16: 1679-1687. http://dx.doi.org/10.1007/s10995-011-0868-8.
Savitz, DA; Elston, B; Bobb, JF; Clougherty, JE; Dominici, F; Ito, K; Johnson, S; Mcalexander, T; Ross, Z; Shmool, JL; Matte, TD; Wellenius, GA. (2015). Ambient fine particulate matter, nitrogen dioxide, and hypertensive disorders of pregnancy in New York City. Epidemiology 26: 748-757. http://dx.doi.org/10.1097/EDE.0000000000000349.
Schembari, A; Nieuwenhuijsen, MJ; Salvador, J; de Nazelle, A; Cirach, M; Dadvand, P; Beelen, R; Hoek, G; Basagaña, X; Vrijheid, M. (2014). Traffic-related air pollution and congenital anomalies in Barcelona. Environ Health Perspect 122: 317-323. http://dx.doi.org/10.1289/ehp.1306802.
Slama, R; Bottagisi, S; Solansky, I; Lepeule, J; Giorgis-Allemand, L; Sram, R. (2013). Short-term impact of atmospheric pollution on fecundability. Epidemiology 24: 871-879. http://dx.doi.org/10.1097/EDE.0b013e3182a702c5.
Slama, R; Gräbsch, C; Lepeule, J; Siroux, V; Cyrys, J; Sausenthaler, S; Herbarth, O; Bauer, M; Borte, M; Wichmann, HE; Heinrich, J. (2010). Maternal fine particulate matter exposure, polymorphism in xenobiotic-metabolizing genes and offspring birth weight. Reprod Toxicol 30: 600-612. http://dx.doi.org/10.1016/j.reprotox.2010.07.001.
Son; J-Y; Bell, ML; Lee; J-T. (2011). Survival analysis of long-term exposure to different sizes of airborne particulate matter and risk of infant mortality using a birth cohort in Seoul, Korea. Environ Health Perspect 119: 725-730. http://dx.doi.org/10.1289/ehp.1002364.
Stieb, DM; Chen, L; Beckerman, BS; Jerrett, M; Crouse, DL; Omariba, DW; Peters, PA; van Donkelaar, A; Martin, RV; Burnett, RT; Gilbert, NL; Tjepkema, M; Liu, S; Dugandzic, RM. (2015). Associations of pregnancy outcomes and PM2.5 in a national Canadian study. Environ Health Perspect 124: 243-249. http://dx.doi.org/10.1289/ehp.1408995.
Stingone, JA; Luben, TJ; Daniels, JL; Fuentes, M; Richardson, DB; Aylsworth, AS; Herring, AH; Anderka, M; Botto, L; Correa, A; Gilboa, SM; Langlois, PH; Mosley, B; Shaw, GM; Siffel, C; Olshan, AF. (2014). Maternal exposure to criteria air pollutants and congenital heart defects in offspring: Results from the national birth defects prevention study. Environ Health Perspect 122: 863-872. http://dx.doi.org/10.1289/ehp.1307289.
Symanski, E; Davila, M; Mchugh, MK; Waller, DK; Zhang, X; Lai, D. (2014). Maternal exposure to fine particulate pollution during narrow gestational periods and newborn health in Harris County, Texas. Matern Child Health J 18: 2003-2012. http://dx.doi.org/10.1007/s10995-014-1446-7.
Trasande, L; Wong, K; Roy, A; Savitz, DA; Thurston, G. (2013). Exploring prenatal outdoor air pollution, birth outcomes and neonatal health care utilization in a nationally representative sample. J Expo Sci Environ Epidemiol 23: 315-321. http://dx.doi.org/10.1038/jes.2012.124.
Tu, J; Tu, W; Tedders, SH. (2016). Spatial variations in the associations of term birth weight with ambient air pollution in Georgia, USA. Environ Int 92-93: 146-156. http://dx.doi.org/10.1016/j.envint.2016.04.005.
Vinikoor-Imler, LC; Davis, JA; Meyer, RE; Luben, TJ. (2013). Early prenatal exposure to air pollution and its associations with birth defects in a state-wide birth cohort from North Carolina. Birth Defects Res A Clin Mol Teratol 97: 696-701. http://dx.doi.org/10.1002/bdra.23159.

Vinikoor-Imler, LC; Davis, JA; Meyer, RE; Messer, LC; Luben, TJ. (2014). Associations between prenatal exposure to air pollution, small for gestational age, and term low birthweight in a state-wide birth cohort. Environ Res 132: 132-139. http://dx.doi.org/10.1016/j.envres.2014.03.040.
Vinikoor-Imler, LC; Gray, SC; Edwards, SE; Miranda, ML. (2012). The effects of exposure to particulate matter and neighbourhood deprivation on gestational hypertension. Paediatr Perinat Epidemiol 26: 91-100. http://dx.doi.org/10.1111/j.1365-3016.2011.01245.x.
Vinikoor-Imler, LC; Stewart, TG; Luben, TJ; Davis, JA; Langlois, PH. (2015). An exploratory analysis of the relationship between ambient ozone and particulate matter concentrations during early pregnancy and selected birth defects in Texas. Environ Pollut 202: 1-6. http://dx.doi.org/10.1016/j.envpol.2015.03.001.
Wallace, ME; Grantz, KL; Liu, D; Zhu, Y; Kim, SS; Mendola, P. (2016). Exposure to ambient air pollution and premature rupture of membranes. Am J Epidemiol 183: 1114-1121. http://dx.doi.org/10.1093/aje/kwv284.
Warren, J; Fuentes, M; Herring, A; Langlois, P. (2012). Spatial-temporal modeling of the association between air pollution exposure and preterm birth: Identifying critical windows of exposure. Biometrics 68: 1157-1167. http://dx.doi.org/10.1111/j.1541-0420.2012.01774.x.
Warren, JL; Stingone, JA; Herring, AH; Luben, TJ; Fuentes, M; Aylsworth, AS; Langlois, PH; Botto, LD; Correa, A; Olshan, AF; NBDPS. (2016). Bayesian multinomial probit modeling of daily windows of susceptibility for maternal PM2.5 exposure and congenital heart defects. Stat Med 35: 2786-2801. http://dx.doi.org/10.1002/sim.6891.
Wilhelm, M; Ghosh, JK; Su, J; Cockburn, M; Jerrett, M; Ritz, B. (2011). Traffic-related air toxics and preterm birth: a population-based case-control study in Los Angeles county, California. Environ Health 10: 89. http://dx.doi.org/10.1186/1476-069X-10-89.
Woodruff, TJ; Darrow, LA; Parker, JD. (2008). Air pollution and postneonatal infant mortality in the United States, 1999-2002. Environ Health Perspect 116: 110-115. http://dx.doi.org/10.1289/ehp.10370.
Wu, J; Ren, C; Delfino, RJ; Chung, J; Wilhelm, M; Ritz, B. (2009). Association between local traffic-generated air pollution and preeclampsia and preterm delivery in the south coast air basin of California. Environ Health Perspect 117: 17731779. http://dx.doi.org/10.1289/ehp.0800334.
Wu, J; Wilhelm, M; Chung, J; Ritz, B. (2011). Comparing exposure assessment methods for traffic-related air pollution in an adverse pregnancy outcome study. Environ Res 111: 685-692. http://dx.doi.org/10.1016/j.envres.2011.03.008.
Xu, X; Hu, H; Ha, S; Roth, J. (2014). Ambient air pollution and hypertensive disorder of pregnancy. J Epidemiol Community Health 68: 13-20. http://dx.doi.org/10.1136/jech-2013-202902.
Yorifuji, T; Kashima, S; Doi, H. (2016). Acute exposure to fine and coarse particulate matter and infant mortality in Tokyo, Japan (2002-2013). Sci Total Environ 551-552: 66-72. http://dx.doi.org/10.1016/j.scitotenv.2016.01.211.
Zhang, B; Liang, S; Zhao, J; Qian, Z; Bassig, BA; Yang, R; Zhang, Y; Hu, K; Xu, S; Zheng, T; Yang, S. (2016). Maternal exposure to air pollutant PM2.5 and PM10 during pregnancy and risk of congenital heart defects. J Expo Sci Environ Epidemiol 26: 422-427. http://dx.doi.org/10.1038/jes.2016.1.
Zhu, Y; Zhang, C; Liu, D; Grantz, KL; Wallace, M; Mendola, P. (2015). Maternal ambient air pollution exposure preconception and during early gestation and offspring congenital orofacial defects. Environ Res 140: 714-720. http://dx.doi.org/10.1016/j.envres.2015.06.002.