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Supplemental Material

Air Pollution (Particulate Matter) Exposure and Associations with Depression, Anxiety, Bipolar, Psychosis and Suicide Risk: A Systematic Review and Meta-Analysis

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Table S1 - Search terms used, organised by database (S1a – Embase search strategy; S1b - OVID Medline search strategy; S1c – PsycINFO search strategy)

S1a: Embase (1 January 1974 to 2017 Week 38) search strategy:	Search term
1	Air Pollution/
2	exp Air Pollutant/
3	exp Particulate Matter/
4	(air adj3 (pollut* or particulate*)).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word]
5	(particulate* adj3 matter).mp.
6	outdoor pollution.mp.
7	polluted air.mp.
8	ultra?fine partic*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word]
9	PM10.mp.
10	PM2?5.mp.
11	air quality.mp.
12	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13	exp Depression/
14	exp mood disorders/
15	exp Depression Assessment/
16	exp Anxiety Disorder/
17	Neurosis/
18	exp Bipolar Disorder/
19	mania.mp.
20	bipolar disorder*.mp.
21	mental disorder*.mp.
22	mental ill health.mp.
23	Psychosis/
24	exp Schizophrenia/
25	affective disorder*.mp.
26	schizophreni*.mp.
27	psychos?s.mp.
28	psychotic.mp.
29	exp suicidal behavior/
30	suicid*.mp.
31	clinical depression.mp.
32	depressive episode*.mp.
33	manic episode*.mp.
34	anxiety disorder*.mp.
35	generali?ed anxiety.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word]
36	(psychiatric adj3 diagnos*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word]

37	(psychiatric adj3 admission).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word]
38	depressive disorder*.mp.
39	manic depression.mp.
40	13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39
41	12 and 40
S1b: OVID Medline (Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily) (1 January 1974 – 20 September 2017) - Search strategy:	Search Term
1	Air Pollution/
2	Air Pollutants/
3	exp Particulate Matter/
4	(air adj3 (pollut* or particulate*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
5	(particulate* adj3 matter).mp.
6	outdoor pollution.mp.
7	polluted air.mp.
8	ultra?fine partic*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
9	PM10.mp.
10	PM2?5.mp.
11	air quality.mp.
12	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13	exp Depression/
14	exp mood disorders/
15	exp Depressive Disorder/
16	exp Anxiety Disorders/
17	Neurotic Disorders/
18	exp Bipolar Disorder/
19	mania.mp.
20	bipolar disorder*.mp.
21	mental disorder*.mp.
22	mental ill health.mp.
23	exp Psychotic Disorders/
24	exp Schizophrenia/
25	affective disorder*.mp.
26	schizophreni*.mp.
27	psychos?s.mp.

28	psychotic.mp.
29	Self-Injurious Behavior/
30	exp Suicide/
31	suicid*.mp.
32	depression.mp.
33	depressive episode*.mp.
34	manic episode*.mp.
35	anxiety disorder*.mp.
36	generali?ed anxiety.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
37	(psychiatric adj3 diagnos*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
38	(psychiatric adj3 admission).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
39	manic depression.mp.
40	depressive disorder*.mp.
41	(psychiatric adj3 disorder*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
42	13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41
43	12 and 42
S1c: PsycINFO (1 January 1974 – 20 September 2017) search strategy:	Search Term
1	(air adj3 (pollut* or particulate*)).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
2	outdoor pollution.mp.
3	polluted air.mp.
4	ultra?fine partic*.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
5	PM10.mp.
6	PM2?5.mp.
7	air quality.mp.
8	exp Depression/
9	exp mood disorders/
10	mania.mp.
11	bipolar disorder*.mp.
12	mental disorder*.mp.
13	mental ill health.mp.
14	exp Schizophrenia/
15	affective disorder*.mp.
16	schizophreni*.mp.
17	psychos?s.mp.

18	psychotic.mp.
19	Self-Injurious Behavior/
20	exp Suicide/
21	suicid*.mp.
22	depression.mp.
23	depressive episode*.mp.
24	manic episode*.mp.
25	anxiety disorder*.mp.
26	generali?ed anxiety.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
27	(psychiatric adj3 diagnos*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
28	(psychiatric adj3 admission).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
29	manic depression.mp.
30	depressive disorder*.mp.
31	(psychiatric adj3 disorder*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
32	exp pollution/
33	particulate*.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
34	exp affective disorders/
35	exp BIPOLAR DISORDER/
36	exp NEUROSIS/
37	exp psychosis/
38	exp anxiety disorders/
39	8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 34 or 35 or 36 or 37 or 38
40	1 or 2 or 3 or 4 or 5 or 6 or 7 or 32 or 33
41	39 and 40

Table S2: covariates adjusted for in studies' adjusted models

Study citation	Confounders included in adjusted models
Long-term exposure only:	
Kim et al. 2016	Stratified by sex and age, and adjusted for household income, smoking status, alcohol consumption, regular exercise, size of the population, proportion of married persons among the population ≥15 years of age, economic and social environment satisfaction, number of clients of the social welfare facilities per capita, and deprivation index in the district in which each participant resided.
Kim and Kim 2017	Adjusted for sex, age, education, labour market participation, comorbidity, sleep hours, physical activity, smoking status and drinking status.
Kioumourtzoglou et al. 2017	Individual level: calendar year and month at questionnaire return, census region, living in a Metropolitan Statistical Area (yes/no), race, physical activity, body mass index, pack-years of smoking, smoking status, dietary habits, multivitamin intake, participation in social groups, baseline abbreviated Mental Health Inventory score, educational level, the education of both of the participant's parents when the participant was 16 years old, marital status, and husband's education, if applicable. Community-level: US 2000 Census data on tract-level median household income, house value, population density.
Lin et al. 2017	Individual level: Age, gender, BMI, education, annual household income, alcohol consumption, physical activity, cooking-related indoor air pollution, smoking. Country level: GDP, percentage in urban areas, per capita healthcare expenditure, Gini coefficient.
Vert et al. 2017	Age, gender, educational attainment, marital status, BMI, living alone, work category, physical activity, smoking, sleep quality, perceived social support, caregiver status
Zijlema et al. 2016:	
a (LifeLines)	Main model: sex, age, level of education, and house-hold income, myocardial infarction, asthma, COPD, and urbanity, road traffic noise
b (KORA)	Main model: sex, age, level of education, and house-hold income, myocardial infarction, asthma, COPD, and urbanity, road traffic noise
c (HUNT)	Alternative confounder model only (socioeconomic and urbanicity data not available): age, sex, asthma, MI, COPD, and road traffic noise
d (FINRISK)	Main model: sex, age, level of education, and house-hold income, myocardial infarction, asthma, COPD, and urbanity, road traffic noise
Long- & short-term exposure	
Power et al. (2015)	Calendar month of questionnaire return, educational attainment, husband's educational attainment, age, age squared, married/has a partner, employment status, physical activity, three residential census tract level characteristics, region of residence, residence within a metropolitan statistical area, social support.
Pun et al. 2017	Multivariable models: age, sex, race, year, season and day of week of questionnaire completion, region of residence, and whether participants lived within a metropolitan statistical area (yes/no), socioeconomic status (individual-specific education attainment and family income, and census-level median household income and % of population with income below poverty level). Wave-specific covariates: individual-specific obesity status, smoking status, physical activity, alcohol consumption/day, UCLA Loneliness scale, use of antidepressant medication, and history of diabetes, hypertension, stroke, heart failure, emphysema, COPD or asthma.
Short-term exposure only	
Bakian et al. 2015	Daily mean temperature, daily mean dew point temperature, and daily mean air pressure, by design: day of the week, month.
Casas et al. 2017	Only control days with a daily average temperature within 2°C of that on the event day were selected. Model adjusted for duration of sunshine (per day) and day of the week.
Kim et al. 2010	National holidays, mean hours of sunlight in the previous 2 days, and cubic splines of meteorological factors: temperature (df=6), the mean temperature of the 3 previous days (df=6), the dew point temperature (df=3), the mean dew point temperature of previous 3 days (df=3), the air pressure (df=3), mean air

	pressure of previous 3 days (df=3). By design: day of the week, month.
Lin et al. 2016	Holidays (indicator variable), daily mean temperature (df=6), relative humidity (df=3), atmospheric pressure (df=3) and sunshine duration (df=3). Natural cubic spline functions of 6-day moving average for the current and previous 5 days for all meteorological factors. By design: day of the week, month.
Ng 2016	Public holidays, the New Year holiday season (first and last two weeks in a year), and the natural splines of daily mean temperature (df=3) and relative humidity (df=3). By design: day of the week, month. Sunshine duration, air pressure (mb) and solar irradiation (MJ/m^3) were not adjusted for to avoid overfitting (analyses showed they did not have significant effects).
Kim et al. 2015	Sunlight hours and temperature, consumer price index, unemployment rate, and stock index valuations, 30 day periods after celebrity suicides with significant Korean TV news coverage. By design: day of the week (data analysed in discrete weekly epochs).
Szyszkowicz et al. 2010	Temperature, relative humidity and date (day of the week, month, year).
Gao et al. 2017	Daily mean temperature, relative humidity, air pressure and sunshine hours, day of the week, sunshine hours and public holidays (dichotomous), long-term trends and seasonality. NO_2, SO_2, O_3 and CO were also included in two-pollutant models.
Cho et al. 2014	Standardized air pollutant concentrations, national holidays, sunlight hours, natural cubic spline of the following variables: temperature (df=30), relative humidity (df=15), and air pressure df=15). The 2-pollutant models including PM_{10} also adjusted for SO_2, NO_2 and CO. Further stratified analyses by season, age group, sex and pre-existing illness.
Szyszkowicz et al., 2007	Daily temperature and humidity. Adjusted for by design: day of the week, month and year
Szyszkowicz et al., 2009	Temperature and relative humidity. Adjusted for by design: location, year, month, day of week
Szyszkowicz et al., 2016	Daily temperature and humidity. Controls matched to cases on day of the week, month and year.
Lim et al. 2012	Factors measured at baseline: age, sex, < or ≥6 years of schooling, BMI, alcohol consumption at least once a month for 10 years or longer, physical activity. Time-varying factors: creatinine-adjusted urinary cotinine level, mean temperature and rainfall level on the day of each visit, visit number and day of the week, serum triglycerides and systolic blood pressure at each visit.
Wang et al. 2014	Short-term analyses: adjusted for age, sex, race/ethnicity, visit, ambient and dew point temperatures, barometric pressure, day of week, season, and long-term temporal trends. Primary long-term analyses: adjusted for age, sex, race/ ethnicity, visit number, season, day of week, household income, education and neighbourhood SES using 2 census tract–level variables: a) % of population that is not non-Hispanic white, and b) % of population with ≥ a college degree. In sensitivity analyses, additionally adjusted for BMI, physical activity, alcohol consumption, smoking, diabetes mellitus, hypertension, hyperlipidaemia, and use of antidepressant medication.

Notes: "Long-term" PM exposure is defined as PM exposure assessed over a period of ≥6 months' duration; "short-term" PM exposure is defined as PM exposure assessed over a period of <6 months' duration and with a lag of <6 months between exposure assessment and outcome assessment. Where a study reported more than one adjusted model, the covariates included in a study's most comprehensively adjusted model are presented except where further detail or explanation is provided within the table. Potential confounding variables have been adjusted for in the analysis stage except where adjustment by design is specified.

Abbreviations: BMI – body mass index; CO – carbon monoxide; COPD – chronic obstructive pulmonary disease, df – degrees of freedom; GDP – gross domestic product, MJ – megajoules; MI – myocardial infarction; NO_2 – nitrogen dioxide; O_3 – ozone; PM – particulate matter; SES – socio-economic status; SO_2 – sulfur dioxide; UCLA – University of California, Los Angeles

Table S3: EPHPP Tool questions and rating descriptors (Summary of questions and descriptors from the McMaster Evidence Review and Synthesis Team (online); Thomas et al., 2004; Armijo-Olivo et al., 2012)

	A. Selection bias	B. Design	C. Confounders	D. Blinding to intervention status and/or research question	E. Data collection methods	F. Withdrawals and dropouts (longitudinal studies only)	Intervention integrity	Analyses
Questions asked to inform the rating of each component:								
1	Are the individuals selected to participate in the study likely to be representative of the target population?	Indicate the study design	Were there important differences between groups prior to the intervention?	Was (were) the outcome assessor(s) aware of the intervention or exposure status of participants?	Were data collection tools shown to be valid?	Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?	What percentage of participants received the allocated intervention or exposure of interest?	Indicate the unit of allocation
2	What percentage of selected individuals agreed to participate?	Was the study described as randomized? If NO, go to Component C.	If yes, indicate the percentage of relevant confounders that were controlled (either by design (e.g. stratification, matching) or analysis)?	Were the study participants aware of the research question?	Were data collection tools shown to be reliable?	Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest).	Was the consistency of the intervention measured?	Indicate the unit of analysis
3		If Yes, was the method of randomization described?					Is it likely that subjects received an unintended intervention (contamination or co-intervention) that may influence the results?	Are the statistical methods appropriate for the study design?
4		If Yes, was the method appropriate?						Is the analysis performed by intention to treat rather than actual intervention received?
Component rating descriptors:								

GOOD	Very likely to be representative of the target population and >80% participation rate	Randomised clinical trial and controlled clinical trial	Controlled for at least 80% of confounders	Blinding of outcome assessor and study participants	Tools are valid and reliable	Follow-up rate of >80% of participants
FAIR	Somewhat likely to be representative of the target population and/or 60–79% participation rate	Cohort analytic, case-control, cohort, or interrupted time series[a]	Controlled for 60–79% of confounders	Blinding of either outcome assessor or study participants	Tools are valid but may not be reliable, or reliability not described	Follow-up rate of 60–79% of participants
POOR	All other responses or not stated	All other designs or design not stated	Confounders not controlled for, or not stated	Outcome assessor and study participants are aware of intervention status and/or research question	No evidence of validity or reliability	Follow-up rate of <60% of participants or not described

[a] Case-only designs (e.g. time series, case-crossover and hierarchical cluster analysis studies) were included in the moderate category for B. study design. Cross-sectional studies with exposure assessed using PM monitoring measurements taken prior to outcome assessment were treated as of equivalent quality to retrospective cohort designs and also rated as moderate.

Table S4 – Population Attributable Fractions (PAF) and Relative Risk calculations associated with current versus counterfactual exposure, using pooled relative risk confidence intervals

			Pooled RR per 10µg/m^3 (from meta-analysis)	Mean population-weighted $PM_{2.5}$ exposure (µg/m^3)		RR (current vs. counterfactual)	PAF ((RR-1)/RR)	PAF (%)
				Current	Counter-factual			
Scen-ario	UK (urban)	Central RR Estimate	1.094	12.8	10.0	1.0252	0.0246	2.46
		95% Lower CI	1.021			1.0058	0.0058	0.58
		95% Upper CI	1.172			1.0454	0.0434	4.34
	Global	Central RR Estimate	1.094	43.9	25.0	1.1830	0.1547	15.47
		95% Lower CI	1.021			1.0401	0.0385	3.85
		95% Upper CI	1.172			1.3498	0.2592	25.92

Abbreviations: CI – Confidence interval; RR – Relative risk; PAF – population attributable fraction; UK – United Kingdom

Table S5: Reasons for exclusion of studies from primary meta-analyses

Study citation	Corresponding meta-analysis or analyses	Reason for exclusion from primary meta-analysis/analyses	Inclusion in sensitivity analyses (where applicable)
KN Kim et al. (2016)	L-T $PM_{2.5}$ and depression	Cohort design (result is a hazard ratio not OR or RR therefore not directly comparable)	1a
Kioumourtzoglou et al. (2017)	L-T $PM_{2.5}$ and depression	Cohort design (result is a hazard ratio not OR or RR therefore not directly comparable)	1a
Vert et al. (2017)	L-T $PM_{2.5}$ and depression; L-T $PM_{2.5}$ and anxiety (M-A not conducted as <3 eligible studies)	Outcome assessed through self-report of a diagnosis of depression. *N.B. This study also excluded patients with major depression or generalized anxiety disorder at baseline (despite being essentially a cross-sectional study), because it was nested within the Alzheimers' and Families (ALFA) cohort)*	1b
HUNT study within Zijlema et al. (2016) (sub-study C)	L-T PM_{10} and depression	No results from a primary adjusted model available for this sub-study (neither urbanicity nor socioeconomic status adjusted for)	
Kim and Kim (2017)	L-T PM_{10} and depression	Outcome assessed through self-report of 'depressive experience' (via the unvalidated binary Yes/No question: 'Have you ever felt sadness or despair in the last two consecutive weeks in the recent year?')	
Szyszkowicz et al. (2007)	S-T PM_{10} and ED visits for depression; S-T $PM_{2.5}$ and ED visits for depression (neither M-A conducted as <3 eligible studies)	Unstratified, whole-year associations with particulate matter not reported at all lags studied. We requested numeric results and confidence intervals but these could not be provided.	
Szyszkowicz et al. (2009)	S-T PM_{10} and ED visits for depression; S-T $PM_{2.5}$ and ED visits for depression (neither M-A conducted as <3 eligible studies)	Unstratified, whole-year associations with particulate matter not reported at all lags studied. We requested numeric results and confidence intervals but these could not be provided.	
Lim et al. (2012)	S-T PM_{10} and depression symptoms (not conducted as <3 eligible studies)	Continuous outcome measure reported (% change in SGDS-K score) - not comparable with the dichotomous outcomes reported by the two other eligible studies of depressive symptom severity.	

Notes: In addition to the reasons for exclusion from meta-analyses presented here we did not conduct meta-analyses for any exposure-outcome combinations for which there were fewer than 3 eligible studies. The information 1a, 1b) listed under the 'inclusion in sensitivity analyses' column corresponds to the 'Sensitivity analysis number' column of the meta-analyses presented in table 4.

Abbreviations: ED – emergency department; L-T – long-term (exposure assessment period >6 months' duration); M-A – meta-analysis; $PM_{2.5}$/PM_{10} – particulate matter of <2.5 or 10 microns' diameter respectively; SGDS-K – short-form geriatric depression scale (Korean version); S-T (exposure period ≤6 months);

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