

**Long-term exposure to fine particulate matter and mortality: a longitudinal cohort study  
of 400,459 adults**

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**eAppendix**

**eTable 1 Characteristics of the participants with cause-specific mortality**

<b>Characteristics</b>	<b>Natural-cause Cancers</b>		<b>Cardiovascular diseases</b>	<b>Influenza and pneumonia</b>
<b>No. (mortality rate /1,000 person-yrs)</b>	<b>13550 (2.7)</b>	<b>6141 (1.22)</b>	<b>2700 (0.54)</b>	<b>645 (0.13)</b>
Age (years)	–	–	–	–
Male (n, %)	8038 (3.3)	3492 (1.4)	1690 (0.7)	420 (0.2)
Education (n, %)				
Lower than high school	7754 (9.6)	3196 (4)	1628 (2)	427 (0.5)
High school	2525 (2.5)	1231 (1.2)	477 (0.5)	106 (0.1)
College or university	2918 (1.1)	1515 (0.6)	528 (0.2)	107 (0)
Postgraduate	353 (0.6)	199 (0.4)	67 (0.1)	5 (0)
Cigarette smoking (n, %)				
Never	8356 (2.3)	3792 (1)	1668 (0.4)	393 (0.1)
Former	1503 (5.4)	588 (2.1)	319 (1.2)	99 (0.4)
Current	3691 (3.6)	1761 (1.7)	713 (0.7)	153 (0.1)
Alcohol consumption (n, %)				
Seldom	10917 (2.5)	4842 (1.1)	2214 (0.5)	546 (0.1)
Occasional	1143 (2.4)	568 (1.2)	210 (0.4)	47 (0.1)
Regular	1490 (6.3)	731 (3.1)	276 (1.2)	52 (0.2)
Physical activity (n, %)				
Inactive	2875 (2.8)	1253 (1.2)	583 (0.6)	142 (0.1)
Low	8485 (3.3)	3742 (1.4)	1710 (0.7)	425 (0.2)
Medium	1297 (1.4)	695 (0.8)	228 (0.2)	51 (0.1)

High-vigorous	893 (1.9)	451 (1)	179 (0.4)	27 (0.1)
Vegetable intake (n, %)				
Seldom	2260 (3.1)	999 (1.4)	458 (0.6)	119 (0.2)
Moderate	7753 (2.6)	3514 (1.2)	1533 (0.5)	351 (0.1)
Frequent	3537 (2.7)	1628 (1.2)	709 (0.5)	175 (0.1)
Fruit intake (n, %)				
Seldom	4600 (2.7)	1998 (1.2)	934 (0.6)	218 (0.1)
Moderate	7378 (2.7)	3435 (1.3)	1452 (0.5)	340 (0.1)
Frequent	1572 (2.6)	708 (1.2)	314 (0.5)	87 (0.1)
Occupational exposure (n, %)	788 (2)	397 (1)	149 (0.4)	28 (0.1)
PM <sub>2.5</sub>				
1 <sup>st</sup> quartile [5.6, 21.5)	3644 (3)	1650 (1.4)	750 (0.6)	177 (0.1)
2 <sup>nd</sup> quartile [21.5, 23.9)	3156 (2.4)	1427 (1.1)	647 (0.5)	161 (0.1)
3 <sup>rd</sup> quartile [23.9, 27.8)	2655 (2.3)	1179 (1)	560 (0.5)	104 (0.1)
4 <sup>th</sup> quartile [27.8, 50.3)	4095 (3.1)	1885 (1.4)	743 (0.6)	203 (0.2)

Statistics are shown as mean (standard deviation) for continuous variables and count (percentage) for categorical variables.

<sup>a</sup> Refers to the 2-year average PM<sub>2.5</sub> exposures for the year of medical visit and the year before.

**eTable 2 Associations between ambient PM<sub>2.5</sub> and mortality by only adjusting for age and sex**

Cause of death	2 <sup>nd</sup> quartile <sup>b</sup>	3 <sup>rd</sup> quartile <sup>b</sup>	4 <sup>th</sup> quartile <sup>b</sup>	Per 10 µg/m <sup>3</sup>
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
All-cause	1.08 (1.03, 1.14)	1.13 (1.07, 1.19)	1.44 (1.32, 1.57)	1.30 (1.24, 1.35)
Natural-cause	1.09 (1.03, 1.14)	1.14 (1.08, 1.20)	1.47 (1.34, 1.60)	1.31 (1.26, 1.37)
Cancer	1.02 (0.95, 1.10)	1.06 (0.98, 1.15)	1.30 (1.13, 1.49)	1.21 (1.13, 1.29)
Cardiovascular diseases	1.23 (1.10, 1.37)	1.31 (1.17, 1.48)	1.61 (1.32, 1.96)	1.42 (1.29, 1.57)
Influenza and pneumonia	1.15 (0.92, 1.45)	1.00 (0.77, 1.29)	1.88 (1.25, 2.82)	1.51 (1.24, 1.85)

Abbreviation: HR, hazard risk; CI, confidence interval; PM<sub>2.5</sub>, particulate matter with aerodynamic diameter < 2.5 µm.

<sup>a</sup> Associations were estimated by adjusting for age and sex.

<sup>b</sup> Cut-off points of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> PM<sub>2.5</sub> quartiles were 21.52 µg/m<sup>3</sup>, 23.89 µg/m<sup>3</sup>, and 27.79 µg/m<sup>3</sup>.

**eTable 3 Associations between ambient PM<sub>2.5</sub> and mortality by not adjusting for lifestyle**

Cause of death	2 <sup>nd</sup> quartile <sup>b</sup>	3 <sup>rd</sup> quartile <sup>b</sup>	4 <sup>th</sup> quartile <sup>b</sup>	Per 10 µg/m <sup>3</sup>
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
All-cause	1.09 (1.04, 1.14)	1.14 (1.08, 1.20)	1.44 (1.32, 1.57)	1.31 (1.26, 1.37)
Natural-cause	1.09 (1.04, 1.15)	1.15 (1.09, 1.21)	1.46 (1.34, 1.60)	1.33 (1.27, 1.39)
Cancer	1.03 (0.95, 1.11)	1.07 (0.99, 1.16)	1.28 (1.12, 1.47)	1.21 (1.14, 1.30)
Cardiovascular diseases	1.23 (1.10, 1.38)	1.32 (1.18, 1.48)	1.62 (1.33, 1.97)	1.45 (1.31, 1.60)
Influenza and pneumonia	1.16 (0.93, 1.46)	1.01 (0.78, 1.30)	1.95 (1.30, 2.91)	1.57 (1.28, 1.91)

Abbreviation: HR, hazard risk; CI, confidence interval; PM<sub>2.5</sub>, particulate matter with aerodynamic diameter < 2.5 µm.

<sup>a</sup> Associations were estimated by adjusting for demographic factors (age, sex, and education), season and year of enrolment.

<sup>b</sup> Cut-off points of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> PM<sub>2.5</sub> quartiles were 21.52 µg/m<sup>3</sup>, 23.89 µg/m<sup>3</sup>, and 27.79 µg/m<sup>3</sup>.

**eTable 4 Associations between ambient PM<sub>2.5</sub> and mortality by further adjusting for health levels**

Cause of death	2 <sup>nd</sup> quartile <sup>b</sup>	3 <sup>rd</sup> quartile <sup>b</sup>	4 <sup>th</sup> quartile <sup>b</sup>	Per 10 µg/m <sup>3</sup>
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
All-cause	1.10 (1.05, 1.15)	1.13 (1.08, 1.19)	1.40 (1.29, 1.53)	1.29 (1.23, 1.34)
Natural-cause	1.10 (1.05, 1.16)	1.14 (1.08, 1.20)	1.42 (1.30, 1.55)	1.30 (1.25, 1.36)
Cancer	1.04 (0.96, 1.12)	1.06 (0.98, 1.15)	1.27 (1.11, 1.45)	1.20 (1.13, 1.28)
Cardiovascular diseases	1.25 (1.11, 1.39)	1.30 (1.16, 1.47)	1.57 (1.29, 1.90)	1.41 (1.27, 1.56)
Influenza and pneumonia	1.16 (0.92, 1.46)	1.00 (0.78, 1.29)	1.88 (1.26, 2.79)	1.54 (1.26, 1.88)

Abbreviation: HR, hazard risk; CI, confidence interval; PM<sub>2.5</sub>, particulate matter with aerodynamic diameter < 2.5 µm.

<sup>a</sup> Associations were estimated by adjusting for demographic factors (age, sex, and education), season, year of enrolment, lifestyle (cigarette smoking, alcohol consumption, physical activity, vegetable and fruit intake, and occupational exposure) and diseases (including diabetes, hypertension, dyslipidaemia, self-reported physician-diagnosed CVD and cancer).

<sup>b</sup> Cut-off points of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> PM<sub>2.5</sub> quartiles were 21.52 µg/m<sup>3</sup>, 23.89 µg/m<sup>3</sup>, and 27.79 µg/m<sup>3</sup>.

**eTable 5 Associations between annual average PM<sub>2.5</sub> exposure and mortality**

Cause of death	2 <sup>nd</sup> quartile <sup>b</sup>	3 <sup>rd</sup> quartile <sup>b</sup>	4 <sup>th</sup> quartile <sup>b</sup>	Per 10 µg/m <sup>3</sup>
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
All-cause	1.13 (1.07, 1.18)	1.17 (1.11, 1.23)	1.55 (1.44, 1.67)	1.36 (1.31, 1.42)
Natural-cause	1.15 (1.09, 1.20)	1.19 (1.13, 1.25)	1.57 (1.46, 1.70)	1.38 (1.33, 1.44)
Cancer	1.08 (1.01, 1.17)	1.08 (1.00, 1.17)	1.37 (1.22, 1.54)	1.27 (1.19, 1.35)
Cardiovascular diseases	1.25 (1.12, 1.40)	1.38 (1.23, 1.55)	1.84 (1.55, 2.18)	1.51 (1.37, 1.65)
Influenza and pneumonia	1.26 (1.00, 1.58)	1.16 (0.91, 1.49)	1.77 (1.24, 2.52)	1.62 (1.35, 1.95)

Abbreviation: HR, hazard risk; CI, confidence interval; PM<sub>2.5</sub>, particulate matter with aerodynamic diameter < 2.5 µm.

<sup>a</sup> Associations were estimated adjusting for demographic factors (age, sex, and education), season, year of enrolment, and lifestyle (cigarette smoking, alcohol consumption, physical activity, vegetable and fruit intake, and occupational exposure).

<sup>b</sup> Cut-off points of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> PM<sub>2.5</sub> quartiles were 21.4 µg/m<sup>3</sup>, 24 µg/m<sup>3</sup>, and 28.2 µg/m<sup>3</sup>, respectively.

**eTable 6 Associations between ambient PM<sub>2.5</sub> and mortality in participants followed up at least 2 years**

Cause of death	2 <sup>nd</sup> quartile <sup>b</sup>	3 <sup>rd</sup> quartile <sup>b</sup>	4 <sup>th</sup> quartile <sup>b</sup>	Per 10 µg/m <sup>3</sup>
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
All-cause	1.10 (1.04, 1.15)	1.13 (1.07, 1.19)	1.41 (1.29, 1.54)	1.30 (1.24, 1.35)
Natural-cause	1.10 (1.05, 1.16)	1.14 (1.08, 1.20)	1.43 (1.30, 1.57)	1.31 (1.26, 1.37)
Cancer	1.04 (0.96, 1.12)	1.06 (0.98, 1.15)	1.26 (1.10, 1.45)	1.19 (1.12, 1.28)
Cardiovascular diseases	1.26 (1.13, 1.42)	1.35 (1.20, 1.52)	1.60 (1.31, 1.96)	1.44 (1.30, 1.60)
Influenza and pneumonia	1.16 (0.92, 1.46)	0.99 (0.76, 1.27)	1.96 (1.31, 2.93)	1.55 (1.26, 1.90)

Abbreviation: HR, hazard risk; CI, confidence interval; PM<sub>2.5</sub>, particulate matter with aerodynamic diameter < 2.5 µm.

<sup>a</sup> Associations were estimated adjusting for demographic factors (age, sex, and education), season, year of enrolment, and lifestyle (cigarette smoking, alcohol consumption, physical activity, vegetable and fruit intake, and occupational exposure).

<sup>b</sup> Cut-off points of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> PM<sub>2.5</sub> quartiles were 21.52 µg/m<sup>3</sup>, 23.89 µg/m<sup>3</sup>, and 27.79 µg/m<sup>3</sup>, respectively.

**eTable 7 Associations between PM<sub>2.5</sub> and mortality by imputing missing data**

Cause of death	2 <sup>nd</sup> quartile <sup>b</sup>	3 <sup>rd</sup> quartile <sup>b</sup>	4 <sup>th</sup> quartile <sup>b</sup>	Per 10 µg/m <sup>3</sup>
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
All-cause	1.11 (1.05, 1.16)	1.15 (1.09, 1.21)	1.45 (1.33, 1.58)	1.31 (1.26, 1.37)
Natural-cause	1.11 (1.05, 1.16)	1.16 (1.10, 1.23)	1.47 (1.35, 1.61)	1.34 (1.28, 1.39)
Cancer	1.04 (0.96, 1.12)	1.08 (1.00, 1.17)	1.27 (1.11, 1.46)	1.22 (1.14, 1.30)
Cardiovascular diseases	1.25 (1.12, 1.40)	1.35 (1.20, 1.52)	1.69 (1.39, 2.06)	1.45 (1.31, 1.60)
Influenza and pneumonia	1.19 (0.95, 1.49)	1.03 (0.80, 1.32)	1.85 (1.23, 2.77)	1.59 (1.30, 1.94)

Abbreviation: HR, hazard risk; CI, confidence interval; PM<sub>2.5</sub>, particulate matter with aerodynamic diameter < 2.5 µm.

<sup>a</sup> Associations were estimated adjusting for demographic factors (age, sex, and education), season, year of enrolment, and lifestyle (cigarette smoking, alcohol consumption, physical activity, vegetable and fruit intake, and occupational exposure).

<sup>b</sup> Cut-off points of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> PM<sub>2.5</sub> quartiles were 21.47 µg/m<sup>3</sup>, 23.9 µg/m<sup>3</sup>, and 27.82 µg/m<sup>3</sup>, respectively.



**eTable 8 Associations between mortality and baseline PM<sub>2.5</sub> exposure in Taiwan**

Cause of death	2 <sup>nd</sup> quartile <sup>b</sup>	3 <sup>rd</sup> quartile <sup>b</sup>	4 <sup>th</sup> quartile <sup>b</sup>	Per 10 µg/m <sup>3</sup>
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
All-cause	0.98 (0.94, 1.03)	0.96 (0.91, 1.01)	0.94 (0.85, 1.04)	0.96 (0.92, 1.00)
Natural-cause	0.99 (0.94, 1.04)	0.96 (0.91, 1.02)	0.94 (0.85, 1.04)	0.96 (0.92, 1.01)
Cancer	0.96 (0.89, 1.03)	0.91 (0.84, 0.98)	0.88 (0.76, 1.03)	0.94 (0.88, 1.00)
Cardiovascular diseases	1.00 (0.89, 1.11)	1.02 (0.91, 1.14)	0.96 (0.76, 1.20)	0.99 (0.89, 1.09)
Influenza and pneumonia	1.12 (0.90, 1.40)	0.81 (0.62, 1.04)	0.80 (0.50, 1.29)	0.86 (0.71, 1.06)

Abbreviation: HR, hazard risk; CI, confidence interval; PM<sub>2.5</sub>, particulate matter with aerodynamic diameter < 2.5 µm.

<sup>a</sup> Associations were estimated adjusting for demographic factors (age, sex, and education), season, year of enrolment, and lifestyle (cigarette smoking, alcohol consumption, physical activity, vegetable and fruit intake, and occupational exposure).

<sup>b</sup> Cut-off points of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> PM<sub>2.5</sub> quartiles were 21.48 µg/m<sup>3</sup>, 23.83 µg/m<sup>3</sup>, and 28.07 µg/m<sup>3</sup>, respectively.

**eTable 9 Associations between mortality and PM<sub>2.5</sub> exposure using the competing risk model**

Cause of death	2 <sup>nd</sup> quartile <sup>b</sup>	3 <sup>rd</sup> quartile <sup>b</sup>	4 <sup>th</sup> quartile <sup>b</sup>	Per 10 µg/m <sup>3</sup>
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
Cancer	1.01 (0.94, 1.09)	1.03 (0.96, 1.11)	1.18 (1.10, 1.27)	1.11 (1.07, 1.15)
Cardiovascular diseases	1.18 (1.06, 1.32)	1.23 (1.10, 1.38)	1.11 (1.00, 1.24)	1.04 (0.99, 1.10)
Influenza and pneumonia	1.08 (0.86, 1.35)	0.88 (0.69, 1.12)	1.39 (1.12, 1.73)	1.24 (1.12, 1.38)

Abbreviation: HR, hazard risk; CI, confidence interval; PM<sub>2.5</sub>, particulate matter with aerodynamic diameter < 2.5 µm.

<sup>a</sup> Associations were estimated adjusting for demographic factors (age, sex, and education), season, year of enrolment, and lifestyle (cigarette smoking, alcohol consumption, physical activity, vegetable and fruit intake, and occupational exposure).

<sup>b</sup> Cut-off points of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> PM<sub>2.5</sub> quartiles were 21.52 µg/m<sup>3</sup>, 23.89 µg/m<sup>3</sup>, and 27.79 µg/m<sup>3</sup>, respectively.

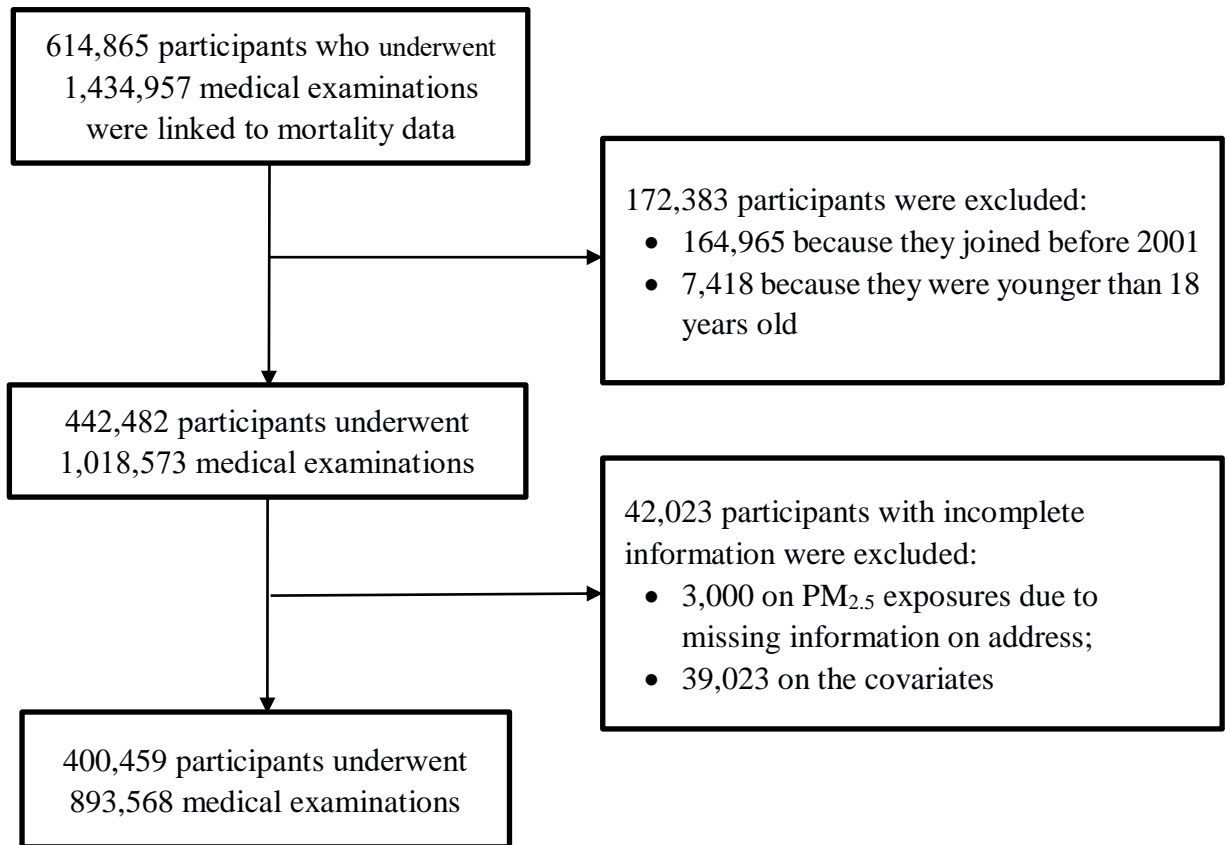
**eTable 10 Associations between mortality and PM<sub>2.5</sub> exposure after adjusting for a city-level random intercept**

Cause of death	2 <sup>nd</sup> quartile <sup>b</sup>	3 <sup>rd</sup> quartile <sup>b</sup>	4 <sup>th</sup> quartile <sup>b</sup>	Per 10 µg/m <sup>3</sup>
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
All-cause	1.08 (1.03, 1.13)	1.11 (1.06, 1.17)	1.26 (1.18, 1.34)	1.25 (1.20, 1.30)
Natural-cause	1.08 (1.03, 1.13)	1.11 (1.06, 1.17)	1.22 (1.17, 1.28)	1.26 (1.21, 1.31)
Cancer	1.02 (0.95, 1.10)	1.04 (0.97, 1.12)	1.19 (1.11, 1.28)	1.12 (1.08, 1.16)
Cardiovascular diseases	1.21 (1.09, 1.35)	1.27 (1.13, 1.42)	1.24 (1.07, 1.44)	1.29 (1.18, 1.41)
Influenza and pneumonia	1.14 (0.91, 1.42)	0.94 (0.74, 1.19)	1.40 (1.13, 1.72)	1.26 (1.13, 1.40)

Abbreviation: HR, hazard risk; CI, confidence interval; PM<sub>2.5</sub>, particulate matter with aerodynamic diameter < 2.5 µm.

<sup>a</sup> Associations were estimated adjusting for demographic factors (age, sex, and education), season, year of enrolment, lifestyle (cigarette smoking, alcohol consumption, physical activity, vegetable and fruit intake, and occupational exposure) and family income.

<sup>b</sup> Cut-off points of the 2<sup>nd</sup>, 3<sup>rd</sup>, and 4<sup>th</sup> PM<sub>2.5</sub> quartiles were 21.52 µg/m<sup>3</sup>, 23.89 µg/m<sup>3</sup>, and 27.79 µg/m<sup>3</sup>, respectively.



**eFigure 1 The procedure for participants' selection**

**eFigure 2. Concentration-response associations between PM<sub>2.5</sub> and deaths from natural-cause, cancers, cardiovascular diseases and influenza and pneumonia.**

Solid lines represent the estimated hazard ratios of mortality and grey bands represent the corresponding 95% confidence intervals. Panels A, B, C, and D represents the concentration-response curves between PM<sub>2.5</sub> and deaths from natural-cause, cancers, cardiovascular diseases and influenza and pneumonia, respectively.

