

Supplementary Material

Health benefit assessment of China's National Action Plan on Air Pollution in the Beijing-Tianjin-Hebei area

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Table of contents

Table S1. PM_{2.5} concentration, population and mortality data of each city in the Beijing-Tianjin-Hebei area.

Table S2. Summary of the meta-analysis of exposure-response coefficients (β).

Table S3. Comparison of meteorological conditions among key cities in the Beijing-Tianjin-Hebei area.

Table S1. PM_{2.5} concentration, population and mortality data of each city in the Beijing-Tianjin-Hebei area.

City	PM _{2.5} concentration (µg m ⁻³)			Population (millions)		Mortality (%)								References
	2013	2017	Under NAPAP	2013	2017	all-cause		cardiovascular		respiratory		lung cancer		
						2017	2013	2017	2013	2017	2013	2017	2013	
Beijing	89	58	62	21.1	20.2	5.20	5.70	3.01	2.89	0.65	0.58	0.56	0.52	Beijing Municipal Bureau of Statistics, 2014, 2018; Beijing Municipal Environmental Protection Bureau, 2018; Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; National Health and Family Planning Commission of the People's Republic of China, 2014, 2017; The People's Government of Beijing Municipality, 2017
Tianjin	96	62	66	14.7	15.6	5.05	6.00	3.38	3.86	0.53	0.57	0.27	0.40	Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; National Health and Family Planning Commission of the People's Republic of China, 2014, 2017; Tianjin Environmental Protection Bureau, 2018; Tianjin Municipal Bureau of Statistics, 2014, 2018; Tianjin Municipal Commission of Health and Family Planning, 2017
Shijiazhuang	156	86	95	10.5	10.9	5.57	6.73	3.31	3.99	0.40	0.48	0.34	0.41	Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017; Shijiazhuang Municipal Bureau of Statistics, 2018
Tangshan	115	66	72	7.5	7.9	4.74	7.70	2.34	3.80	0.28	0.46	0.33	0.54	Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017; Tangshan Municipal Bureau of Statistics, 2018
Qinhuangdao	65	44	47	3.0	3.1	6.69	7.08	3.48	3.68	0.42	0.44	0.49	0.52	Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al.,

Handan	138	86	93	10.1	9.5	7.05	6.51	3.67	3.39	0.44	0.41	0.53	0.48	2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017; Qinhuangdao Municipal Bureau of Statistics, 2017 Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Handan Municipal Bureau of Statistics, 2018; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017
Xingtai	160	80	90	7.6	7.9	7.01	6.93	3.64	3.60	0.45	0.44	0.51	0.51	Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017; Xingtai Municipal Bureau of Statistics, 2018
Baoding	135	84	90	10.2	10.5	5.79	6.83	3.01	3.55	0.36	0.43	0.42	0.50	Baoding Municipal Bureau of Statistics, 2017; Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017
Zhangjiakou	40	31	32	4.7	4.7	5.90	7.38	3.07	3.84	0.36	0.46	0.43	0.54	Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017; Zhangjiakou Municipal Bureau of Statistics, 2018
Chengde	49	35	37	3.8	3.8	6.41	7.35	3.33	3.82	0.40	0.46	0.47	0.54	Chengde Municipal Bureau of Statistics, 2018; Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017
Cangzhou	102	66	71	7.5	7.8	6.61	6.74	3.44	3.50	0.41	0.42	0.49	0.50	Cangzhou Municipal Bureau of Statistics, 2018; Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of

															Statistics, 2014, 2017
Langfang	110	60	66	4.4	4.7	3.88	6.45	2.02	3.35	0.25	0.41	0.29	0.48	Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017; Langfang Municipal Bureau of Statistics, 2018	
Hengshui	122	77	83	4.5	4.5	3.14	6.78	1.63	3.53	0.20	0.43	0.23	0.50	Ministry of Ecology and Environment of the People's Republic of China, 2018; Fang et al., 2016; Hebei Province Environmental Protection Hall, 2014, 2018; Hebei Provincial Bureau of Statistics, 2014, 2017; Hengshui Municipal Bureau of Statistics, 2018	

Parameters were obtained in the following order: first, from official statistics, obtained for all PM_{2.5} concentrations and all-cause mortalities, the majority of populations and a minority of the three specific disease mortalities; second, from relative studies, obtained for the majority of the mortalities of the three diseases; and finally, from estimation from existing data, obtained for a minority of populations and the mortalities of the three diseases. For example, the 2017 population of Tangshan was calculated from the population and the population growth rate in 2016 from official statistics, while the 2017 mortalities of the three specific diseases in Chengde were determined by assuming that each specific disease mortality was proportional to the all-cause mortality, and all four 2013 mortalities and the 2017 all-cause mortality were obtained from correlation studies.

References

Baoding Municipal Bureau of Statistics. (2016). National economic and social development statistical bulletin of Baoding 2016. <http://www.bdtj.gov.cn/shownews.asp?nid=560>, Last Access: 05 June 2017.

Beijing Municipal Bureau of Statistics. (2014). *Beijing Statistical Yearbook 2014*. China Statistics Press, Beijing, China.

Beijing Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Beijing 2017. <http://www.bjstats.gov.cn/tjsj/tjgb/ndgb/201803/P020180302397365111421.pdf>, Last Access: 19 January 2018.

Beijing Municipal Environmental Protection Bureau. (2018). 2017 Beijing environmental air quality status. <http://www.bjepb.gov.cn/bjhrb/xxgk/ywdt/hjzlk/dqhjzl/829056/index.html>, Last Access: 07 February 2018.

Cangzhou Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Cangzhou 2017. http://www.tj.cangzhou.gov.cn/H_BSC/Services/AttachDownload.jsp?id=514466, Last Access: 16 March 2018.

Chengde Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Chengde 2017. http://cdtj.gov.cn/news_show.aspx?id=12190, Last Access: 24 February 2018.

- Fang, D., Wang, Q.G., Li, H., Yu, Y., Lu, Y., Qian, X. (2016). Mortality effects assessment of ambient PM_{2.5} pollution in the 74 leading cities of China. *Sci. Total Environ.* 569-570, 1545-1552.
- Handan Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Handan 2017. <http://tj.hd.gov.cn/html/tjxx/97403064604.html>, Last Access: 02 March 2018.
- Hebei Province Environmental Protection Hall. (2014). Hebei province environment condition bulletin 2013. <http://www.hebhb.gov.cn/hjzlkzgb/201406/P020140606552933555911.pdf>, Last Access: 06 June 2014.
- Hebei Province Environmental Protection Hall. (2018). The ranking of environmental air quality in Hebei province in 2017. http://www.hebhb.gov.cn/ttxw/201802/t20180223_61500.html, Last Access: 23 January 2018.
- Hebei Provincial Bureau of Statistics. (2014). *Hebei Economic Yearbook 2014*. China Statistics Press, Beijing, China.
- Hebei Provincial Bureau of Statistics. (2017). *Hebei Economic Yearbook 2017*. China Statistics Press, Beijing, China.
- Hengshui Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Hengshui 2017. http://www.hstjj.gov.cn/mtyz/2018/04/04/content_470895.shtml, Last Access: 04 April 2018.

Langfang Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Langfang 2017.

<http://www.lf.gov.cn/Item/77368.aspx>, Last Access: 02 April 2018.

Ministry of Ecology and Environment of the People's Republic of China. (2018). The regular press conference record of Ministry of Ecology and Environment of the People's Republic of China in February 2018.

http://www.mep.gov.cn/gkml/sthjbgw/qt/201802/t20180227_431875.htm, Last Access: 08 March 2018.

National Health and Family Planning Commission of the People's Republic of China. (2014). *National Health and Family Planning Statistics Yearbook of China 2014*.

Peking Union Medical College Press, Beijing, China.

National Health and Family Planning Commission of the People's Republic of China. (2017). *National Health and Family Planning Statistics Yearbook of China 2017*.

Peking Union Medical College Press, Beijing, China.

Qinhuangdao Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Qinhuangdao 2016.

<http://www.qhdttj.gov.cn/html/2017/4-4/n245136119.html>, Last Access: 04 May 2017.

Shijiazhuang Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Shijiazhuang 2017.

<http://www.sjztj.gov.cn/hscms/webpage/001/article.jsp?fchannelidentity=%E7%B B%9F%E8%AE%A1%E5%85%AC%E6%8A%A5&articleId=8a8da0b061c6d4de016275e6e69f2c74&tp=1>, Last Access: 30 March 2018.

Tangshan Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Tangshan 2017. <http://www.tangshan.gov.cn/zhuzhan/tjxxnb/20180403/582427.html>, Last Access: 30 March 2018.

The People's Government of Beijing Municipality. (2017). *Beijing Health and Population Health Report 2016*. People's Medical Publishing House Co., LTD, Beijing, China.

Tianjin Environmental Protection Bureau. (2018). Tianjin environmental air quality report for December and full year of 2017. http://hjbh.tj.gov.cn/root16/mechanism_1006/environmental_monitoring_center/201801/t20180115_30847.html, Last Access: 15 February 2018.

Tianjin Municipal Bureau of Statistics. (2018). *Tianjin Statistics Yearbook 2014*. China Statistics Press, Beijing, China.

Tianjin Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Tianjin 2017. <http://stats.tj.gov.cn/Item/27643.aspx>, Last Access: 11 March 2018.

Tianjin Municipal Commission of Health and Family Planning. (2018). Tianjin residents health status report 2016. <http://www.tjwsj.gov.cn/UploadPath/2017/8/11/64678800876ac3-80a6-4611-a410-8aa500206f6d.doc>, Last Access: 11 August 2017.

Xingtai Municipal Bureau of Statistics. (2018). National economic and social development statistical bulletin of Xingtai 2017.

<http://www.xtstj.gov.cn/xttj/gdxw/101521449405145.html>, Last Access: 22
March 2018.

Zhangjiakou Municipal Bureau of Statistics. (2018). National economic and social
development statistical bulletin of Zhangjiakou 2017.
<http://www.zjktj.gov.cn/Message.asp?ArticleId=1028>, Last Access: 27 March
2018.

Table S2. Summary of the meta-analysis of exposure-response coefficients (β).

Reference	β (SE ^a , %/10 $\mu\text{g m}^{-3}$) of different causes of death				
	all cause	cardiovascular	respiratory	lung cancer	
Badaloni et al., 2017	2.96(0.99)	4.88(1.46)	-	-	
Cao et al., 2011	0.90(0.54)	2.80(0.94)	0.90(1.48)	3.40(1.89)	
Guo et al., 2016	-	-	-	7.14(0.69)	
Li et al., 2018	7.70(0.71)				
Liang et al., 2018	16.78(3.25)	3.72(3.96)	44.14(13.1)	-	
Pinault et al., 2016	23.19(2.95)	-	42.00(9.76)	15.44(9.16)	
Pinault et al., 2017	16.30(1.28)	21.99(2.35)	19.56(4.36)	14.67(3.96)	
Turner et al., 2016	3.92(0.98)	6.77(1.43)	10.44(2.98)	12.22(3.38)	
Wong et al., 2015	13.10(3.35)	35.07(10.20)	4.88(7.76)	-	
Wong et al., 2016	-	-	-	13.10(8.89)	
Yang et al., 2018	2.96(1.23)	5.83(1.93)	1.0(2.53)	-	
Yin et al., 2017	8.62(0.24)	8.62(0.47)	-	11.33(1.62)	
Zhou et al., 2014	2.50(0.74)	2.80(0.84)	2.60(1.12)	-	
	4.30(1.06)	4.97(1.26)	6.69(2.33)	4.66(0.73)	
	Heterogeneity				
Ours	(I^2) ^b	94%	86%	83%	54%
	Overall	Z=6.71	Z=5.90	Z=2.94	Z=6.33
	effect ^c	($P<0.00001$)	($P<0.00001$)	($P=0.003$)	($P<0.00001$)

^a standard error.

^b when $I^2 < 50\%$, the heterogeneity among studies is relatively low, and the fixed effect model is a more appropriate choice for meta-analysis; when $I^2 \geq 50\%$, the heterogeneity is relatively high, and the random effects model, as used in our study, is more suitable.

^c when $P < 0.05$, as with our β , the results have statistical significance.

References

- Badaloni, C., Cesaroni, G., Cerza, F., Davoli, M., Brunekreef, B. and Forastiere, F. (2017). Effects of long-term exposure to particulate matter and metal components on mortality in the Rome longitudinal study. *Environ. Int.* 109:146-154.
- Cao, J., Yang, C., Li, J., Chen, R., Chen, B., Gu, D. and Kan, H. (2011). Association between long-term exposure to outdoor air pollution and mortality in China: a cohort study. *J. Hazard Mater.* 186: 1594-1600.
- Guo, Y.M., Zeng, H.M., Zheng, R.S., Li, S.S., Barnett, A.G., Zhang, S.W., Zou, X.N., Huxley, R., Chen, W.Q., and Williams, G. (2015). The association between lung cancer incidence and ambient air pollution in China: a spatiotemporal analysis. *Environ. Res.* 144: 60-65.
- Li, T.T., Zhang, Y., Wang, J.N., Xu, D.D., Yin, Z.X., Chen, H.SH., Lv, Y.B., Luo, J.S., Zeng, Y., Liu, Y., Kinney, P.L. and Shi, X.M. (2018). All-cause mortality risk associated with long-term exposure to ambient PM_{2.5} in China: a cohort study. *The Lancet Public Health.* 3(10): 470-477.
- Liang, F.CH., Xiao, Q.Y., Gu, D.F., Xu, M.M., Tian, L., Guo, Q., Wu, Z.T., Pan, X.CH. and Liu, Y. (2018). Satellite-based short- and long-term exposure to PM_{2.5}, and adult mortality in urban Beijing, China ~~Environ. Pollut.~~ *Environ. Pollut.* 242: 492-499.
- Pinault, L., Tjepkema, M., Crouse, D. L., Weichenthal, S., Donkelaar, A.V., Martin, R.V., Brauer, M., Chen, H. and Burnett, T. (2016). Risk estimates of mortality attributed to low concentrations of ambient fine particulate matter in the Canadian community health survey cohort. *Environ Health.* 15(1): 1-15.

- Pinault, L.L., Weichenthal, S., Crouse, D.L., Brauer, M., Erickson, A., Donkelaar, A.V., Martin, R.V., Hystad, P., Chen, H., Finès, P., Brook, J.R., Tjepkema, M. and Burnett, R.T. (2017). Associations between fine particulate matter and mortality in the 2001 Canadian Census Health and Environment Cohort. *Environ. Res.* 159: 406-415.
- Turner, M.C., Jerrett, M., Pope III, C.A., Krewski, D., Gapstur, S.M., Diver, W.R., Beckerman, B.S., Marshall, J.D., Su, J., Crouse, D.L. and Burnett, R.T. (2016). Long-term ozone exposure and mortality in a large prospective study. *Am. J. Respir. Crit. Care Med.* 193(10): 1134-1142.
- Wong, C.M., Lai, H.K., Tsang, H., Thach, T.Q., Thomas, G.N., Lam, K.B.H., Yang, L., Lau, A.K.H, Ayres, J.G., Lee, S.Y., Chan, W.M., Hedley, A.J. and Lam, T.H. (2015). Satellite-based estimates of long-term exposure to fine particles and association with mortality in elderly Hongkong residents. *Environ. Health Perspect.* 123(11): 1167-1172.
- Wong, C.M., Tsang, H., Lai, H.K., Thomas, G.N., Lam, K.B., Chan, K.P., Zheng, Q.SH., Ayres, J.G., Lee, S.Y., Lam, T.H. and Thach, T.Q. (2016). Cancer mortality risks from long-term exposure to ambient fine particle. *Cancer Epidemiol., Biomarkers Prev.* 25(5): 839-845.
- Yang, Y., Tang, R., Qiu, H., Lai, P.C., Wong, P., Thach, T.Q., Allen, R., Brauer, M., Tian, L.W. and Barratt, B. (2018). Long term exposure to air pollution and mortality in an elderly cohort in Hong Kong. *Environ. Int.* 117: 99-106.
- Yin, P., Brauer, M., Cohen, A., Burnett, R.T., Liu, J., Liu, Y., Liang, R., Wang, W., Qi, J., Wang, L. and Zhou M. (2017). Long-term fine particulate matter exposure and

nonaccidental and cause-specific mortality in a large national cohort of chinese men. *Environ. Health Perspect.* 125(11): 117002.

Zhou, M., Liu, Y., Wang, L., Kuang, X., Xu, X. and Kan, H. (2014). Particulate air pollution and mortality in a cohort of chinese men. *Environ. Pollut.* 186: 1-6.

Table S3. Comparison of meteorological conditions among key cities in the Beijing-Tianjin-Hebei area.

	Beijing		Tianjin		Shijiazhuang	
	2017	2013	2017	2013	2017	2013
Average Relative Humidity (%)	52.6	57.3	55.5	59.8	56.3	61.9
Average Wind Speed (m/s)	1.9	1.8	2.1	2.0	1.7	1.7

References

China National Meteorological Data Service Center. (2018). National Meteorological Information Center, <http://data.cma.cn/>, Last Access: 20 October 2017.