CHINA CDC WEEKLY





Preplanned Studies Incidence of Eczema in Early Infancy and the Prenatal Risk Factors — Guangzhou, Guangdong, China, 2018–2019 Projection of Temperature-Related Excess Mortality by Integrating Population Adaptability Under Changing Climate — China, 2050s and 2080s

Outbreak Reports

Norovirus Detection in Environmental Samples from Norovirus Outbreaks in Schools and Kindergartens — Beijing Municipality, China, October –December 2020

Policy Notes

First Technical Specifications for Health Risk Assessment of Ambient Air Pollution in China

706

702









China CDC Weekly

Editorial Board

Editor-in-Chief	George	F.Gao	
Deputy Editor-in-	Chief	Liming Li	Gabriel M Leung
Executive Editor	Feng	Tan	

Members of the Editorial Board

Xiangsheng Chen	Xiaoyou Chen
Gangqiang Ding	Xiaoping Dong
Xi Jin	Biao Kan
Tao Li	Zhongjie Li
Jinxing Lu	Huiming Luo
Jun Ma	Ron Moolenaar (USA)
RJ Simonds (USA)	Ruitai Shao
Yuelong Shu	Xu Su
Hongqiang Sun	Quanfu Sun
Hongqiang Sun Kanglin Wan	Quanfu Sun Huaqing Wang
Hongqiang Sun Kanglin Wan Jing Wu	Quanfu Sun Huaqing Wang Weiping Wu
Hongqiang Sun Kanglin Wan Jing Wu Zunyou Wu	Quanfu Sun Huaqing Wang Weiping Wu Lin Xiao
Hongqiang Sun Kanglin Wan Jing Wu Zunyou Wu Hong Yan	Quanfu Sun Huaqing Wang Weiping Wu Lin Xiao Hongyan Yao
Hongqiang Sun Kanglin Wan Jing Wu Zunyou Wu Hong Yan Shicheng Yu	Quanfu Sun Huaqing Wang Weiping Wu Lin Xiao Hongyan Yao Xuejie Yu (USA)
Hongqiang Sun Kanglin Wan Jing Wu Zunyou Wu Hong Yan Shicheng Yu Rong Zhang	Quanfu Sun Huaqing Wang Weiping Wu Lin Xiao Hongyan Yao Xuejie Yu (USA) Tiemei Zhang

Zijian Feng

Zhuo Chen (USA) Mengjie Han Haidong Kan Min Liu Huilai Ma Daxin Ni Yiming Shao Chengye Sun Xin Sun Linhong Wang Xifeng Wu (USA) Fujie Xu (USA) Zundong Yin Jianzhong Zhang Wenhua Zhao

Maigeng Zhou

Xianbin Cong Guangxue He Qun Li Qiyong Liu Jiagi Ma Lance Rodewald (USA) Xiaoming Shi Dianjun Sun **Jinling Tang** Guizhen Wu Yongning Wu Wenbo Xu Hongjie Yu Liubo Zhang Yanlin Zhao Xiaonong Zhou

Advisory Board

Director of the Advisory B	oard Jiang Lu		
Vice-Director of the Advis	ory Board Yu Wang Jianj	un Liu	
Members of the Advisory	Board		
Chen Fu	Gauden Galea (Malta)	Dongfeng Gu	Qing Gu
Yan Guo	Ailan Li	Jiafa Liu	Peilong Liu
Yuanli Liu	Roberta Ness (USA)	Guang Ning	Minghui Ren
Chen Wang	Hua Wang	Kean Wang	Xiaoqi Wang
Zijun Wang	Fan Wu	Xianping Wu	Jingjing Xi
Jianguo Xu	Jun Yan	Gonghuan Yang	Tilahun Yilma (USA)
Guang Zeng	Xiaopeng Zeng	Yonghui Zhang	

Editorial Office

Directing Editor	Feng Tan			
Managing Editors	Lijie Zhang	Yu Chen	Peter Hao (USA)	
Senior Scientific Ed	itors Ning Wang	Ruotao Wang	Shicheng Yu	Qian Zhu
Scientific Editors	Weihong Chen	Xudong Li	Nankun Liu	Lu Ran
	Xi Xu	Qing Yue	Xiaoguang Zhang	Ying Zhang

Cover Photo: Beijing CDC Staff Sampling for norovirus on doorknob in a Beijing school, October 23, 2020.

Incidence of Eczema in Early Infancy and the Prenatal Risk Factors — Guangzhou, Guangdong, China, 2018–2019

Liting Deng^{1,&}; Huihui Liu^{1,2,&}; Dongmei Wei^{1,2}; Jinhua Lu^{1,2}; Chengrui Wang¹; Songying Shen¹; Jianrong He^{1,2}; Xiu Qiu^{1,2,#}

Summary

What is already known on this topic?

Eczema is a common allergic disease in children, which seriously affects the quality of life of children and their families.

What is added by this report?

The results showed that the incidence of very-earlyonset eczema was 12.4%. Primiparity was associated with a higher risk of eczema [risk ratio (95% confidence interval): 1.23 (1.06–1.42)].

What are the implications for public health practice?

Very-early-onset eczema is common. Given its adverse impact on children's health and life quality, this previously neglected public health issue needs to be prioritized. In addition, maternal parity could serve as an indicator in risk assessment and prediction for infant eczema.

Eczema is a common chronic disease in children, characterized by recurrent episodes of skin lesion and pruritus (1). Eczema is the first manifestation of "atopic march" and can lead to a higher risk of developing other allergic diseases later in life (2). However, the epidemiologic characteristics of eczema in very early life are still unclear. This study estimated the incidence of very-early onset of eczema, defined as diagnosed before six weeks of age, among infants born in Guangzhou, China, between 2018 and 2019, and it explored its related prenatal risk factors. The incidence of very-early-onset eczema was 12.4% in this population, and primiparity was associated with a higher risk of eczema {relative risk (RR) [95% confidence interval (CI)]: 1.23 (1.06–1.42)}. These findings indicate prenatal factors could have an important role in the development of infant eczema. The high incidence of infant eczema should receive more attention, and more research is needed to investigate the etiology of infant eczema and explore potential primary prevention strategies.

The present study was based on data collected from the Born in Guangzhou Cohort Study (BIGCS), which is a prospective birth cohort study conducted by the Guangzhou Women and Children's Medical Center (GWCMC), China. Women were recruited during their first routine antenatal appointment (<20 weeks of gestation) at two different sites of GWCMC. Motherinfant dyads were included for this analysis if the infant was born between January 2018 and December 2019 and completed a follow-up at six weeks of age. Exclusion criteria excluded mothers with multiple pregnancies, withdrawn from the study after delivery, or whose infants died during the first six weeks postpartum. The Institute Ethics Committee of GWCMC has approved the study, and all participants provided written informed consent at enrollment.

The outcome of interest was very-early-onset eczema (i.e., eczema onset before 6 weeks of age). Information on infant eczema was collected via a self-administrative questionnaire modified from the validated version of International Study of Asthma and Allergies in Childhood. The parents were asked to choose yes or no to the question "has your child ever had atopic eczema diagnosed by a physician after birth?" during a followup at six-weeks postpartum. Other maternal information, including demographic characteristics, environmental exposure, and health conditions during pregnancy, was collected at enrollment via a validated questionnaire. Pre-pregnancy body mass index (BMI) (kg/m²) was categorized into four groups: underweight (BMI <18.5 kg/m²), normal (BMI 18.5–23.9 kg/m²), overweight (BMI 24.0-27.9 kg/m²), and obesity (BMI $\geq 28.0 \text{ kg/m}^2$) based on Chinese standards (3). Differences in participants' characteristics by infant eczema status (yes/no) were examined using the chisquared test for categorical data and Student's t-test for continuous variables. The incidence of eczema was calculated by dividing the number of infants diagnosed with eczema by the total number of infants included in the analysis. Poisson regression models were performed to investigate the association between potential risk

factors and very-early-onset eczema, and RR and 95% CI were calculated. Statistical analyses were performed using SAS (version 9.4, SAS Institute Inc., Cary, NC, USA).

A total of 10,085 singleton-born infants [follow-up rate of 90.6% (10,085/11,130)] had information on eczema diagnosis at six weeks of age and were included in the current analysis. Among these infants, 12.4% (n=1,247) had very-early-onset eczema. Table 1 summarized the maternal and infant characteristics by very-early-onset eczema status (yes/no). The incidence of very-early-onset eczema among infants of

primiparous mothers was higher than that among infants of multiparous mothers (13.4% vs. 10.8%, P<0.01). Statistically significant differences were not found between infants with or without very-early-onset eczema in other maternal and infant characteristics, including maternal age, maternal monthly income, maternal education level, pre-pregnancy BMI, tobacco exposure during early pregnancy, maternal history of allergy, pets during pregnancy, proportion of cesarean section, gestational diabetes mellitus, hypertensive disorders in pregnancy, gestational age, and infant sex. Results for associations of each potential prenatal risk

TABLE 1. Maternal and infant characteristics according to very-early-onset eczema in Guangzhou, Guangdong, China, 2018–2019.

Characteristics	With very-early-onset eczema (n=1,247)	Without very-early-onset eczema (n=8,838)	P-value
Maternal age, years, mean±SD	30.5±3.8	30.6±4.0	0.30
Maternal monthly income, CNY, n (%)			0.22
≤1,500	91(8.1)	685(8.4)	
1,501–4,500	130(11.6)	1,115(13.6)	
4,501–9,000	454(40.5)	3,305(40.4)	
≥9,001	447(39.8)	3,078(37.6)	
Maternal education level, n (%)			0.08
Middle school or below	78(6.3)	721(8.2)	
College	283(22.7)	2,017(22.8)	
Undergraduate	673(54.0)	4,724(53.5)	
Postgraduate or above	213(17.1)	1,376(15.6)	
Pre-pregnancy BMI, kg/m², n (%)			0.65
<18.5	241(20.9)	1,645(19.9)	
18.5–23.9	783(68.0)	5,631(68.2)	
24.0–27.9	110(9.6)	828(10.0)	
≥28.0	17(1.5)	155(1.9)	
Tobacco exposure during early pregnancy, n (%)	323(27.1)	2,309(26.8)	0.85
Drinking during early pregnancy, n (%)	63(5.3)	436(5.1)	0.75
Maternal history of allergy, n (%)			
Eczema	81(6.8)	517(6.0)	0.31
Rhinitis	195(16.3)	1,329(15.4)	0.45
Asthma	9(0.8)	40(0.5)	0.19
Pets during pregnancy, n (%)	171(14.2)	1,144(13.3)	0.35
Cesarean section, n (%)	336(27.0)	2,485(28.2)	0.37
Primipara, n (%)*	814(65.3)	5,243(59.3)	<0.01
Gestational diabetes mellitus, n (%)	211(17.0)	1,477(16.8)	0.88
Hypertensive disorders in pregnancy, n (%)	61(4.9)	401(4.6)	0.59
Gestational age, weeks, mean±SD	39.3±1.2	39.2±1.4	0.11
Male child, n (%)	672(53.9)	4,603(52.1)	0.25

Abbreviations: BMI=body mass index; SD=standard deviation.

* Statistically significant.

factor with very-early-onset eczema were also shown in Figure 1. Primiparity was associated with increased risk of very-early-onset eczema [RR (95% CI): 1.23 (1.06–1.42)]. No statistically significant association was found for other prenatal factors.

DISCUSSION

This study shows that the incidence of eczema onset in very early infancy was 12.4%. Parity was associated with a higher risk of very-early-onset eczema. Understanding the incidence of very-early-onset eczema and exploring its related risk factors may help facilitate early identification of the population that is at high-risk of developing allergic disease later in life and thus enable early and effective interventions. The incidence of very-early-onset eczema reported in this study was at a similar level as those reported in two other studies conducted in Japan (12.1%) (4) and in the United Kingdom (11.6%) (5). The present finding suggests that eczema affects a substantial proportion of infants in very early life in Guangzhou City, Guangdong Province, China.

The Origin of Development of Health and Disease theory suggests that factors in early life may contribute to the development or progression of disease in childhood and later in life (6). The current study showed that infants of primiparous mothers are more likely to have very-early-onset eczema compared to those of multiparous mothers. This finding can be explained as having more siblings increased the chance of infection in early life, which could reduce the occurrence of allergies by inhibiting the proliferation of

Characteristics	Very-e	early-onset eczema
Maternal age, years	1.01 (0.99-1.02)	÷
Maternal monthly income, CNY		
≤1,500	1.18 (0.90-1.56)	
1,501-4,500	1.00	+
4,501-9,000	1.11 (0.90–1.36)	
≥9,001	1.12 (0.90-1.40)	
Maternal education level		
Senior high school or below	1.00	+
College	1.23 (0.93–1.64)	+
Undergraduate	1.21 (0.92–1.60)	+
Postgraduate or above	1.29 (0.94–1.75)	
Pre-pregnancy BMI, kg/m ²		
<18.5	1.04 (0.90-1.22)	-
18.5-23.9	1.00	+
24.0-27.9	0.95 (0.77-1.17)	-
≥28.0	0.65 (0.38-1.14)	
Tobaccoexposure during early pregnancy	1.00 (0.87–1.15)	+
Drinking during early pregnancy	0.96 (0.73-1.27)	
Maternal history of allergy		
Eczema	1.07 (0.84–1.37)	
Rhinitis	1.01 (0.85–1.19)	+
Asthma	1.59 (0.82–3.09)	\rightarrow
Pets during pregnancy	0.98 (0.82–1.17)	+
Cesarean section	1.01 (0.87–1.16)	+
Primipara*	1.23 (1.06–1.42)	
Gestational diabetes mellitus	1.04 (0.88–1.22)	+
Hypertensive disorders in pregnancy	1.15 (0.86–1.53)	
Gestational age, weeks	1.02 (0.98–1.07)	+
Male child	1.07 (0.95–1.21)	-8-
	0.2	10 20
	RR	2 (95% CD
	1111	· · · · · · · · · · · · · · · · · ·

FIGURE 1. The risk factors of very-early-onset eczema in Guangzhou, Guangdong, China, 2018–2019. Abbreviations: BMI=body mass index; CI=confidence interval; RR=rate ratio. * Statistically significant.

Th2 cells (7).

Findings from this study have important public health implications. Although it is not a lifethreatening condition, eczema can substantially affect the patients' quality of life and may have a long-term impact on their health. According to the Global Burden of Disease study 2019, it is estimated that eczema caused about one million disability-adjusted life years in China (8). More importantly, very-earlyonset eczema is an indication of altered immune function in early life, which could increase the risk of subsequent allergic diseases. The current study found the incidence of very-early-onset eczema was as high as 12.4% in Guangzhou City in 2018-2019. This finding suggested that the prevention of early-onset eczema should be prioritized to improve child health. Furthermore, maternal parity was associated with risk of infant eczema in the present study. This finding also suggested future directions to identify populations at higher risk of developing eczema and the window of opportunity to intervene.

The current study has several strengths. The prospective cohort design likely reduced potential recall bias, and the large sample size with a low attrition rate ensured sufficient statistical power to detect a modest effect.

The study was also subject to some limitations. First, the potential residual confounding by unmeasured factors. Second, the eczema infant in the present study was assessed based on doctor's diagnosis. Thus it might only represent the severe cases that require medical attention.

In conclusion, the current study showed that the incidence of very-early-onset eczema was as high as 12.4% in Guangzhou, Guangdong, China. Infants of mothers who were primiparous had a higher risk of eczema. These findings suggested that efforts should be made to evaluate and prevent very-early-onset eczema, especially among primiparous mothers.

Acknowledgements: All participant mothers and their children in the Born in Guangzhou Cohort Study; all participating obstetric care providers who assisted in the implementation of the study; and the Born in Guangzhou Cohort Study team.

Funding: The National Natural Science Foundation of China (grant numbers 81673181), Department of Science and Technology of Guangdong Province (grant number 2019B030316014), Guangzhou Science Technology and Innovation Commission (201807010086).

doi: 10.46234/ccdcw2021.173

[#] Corresponding author: Xiu Qiu, qiu.xiu@bigcs.org.

Submitted: May 26, 2021; Accepted: June 11, 2021

REFERENCES

- Ramirez FD, Chen S, Langan SM, Prather AA, McCulloch CE, Kidd SA, et al. Association of atopic dermatitis with sleep quality in children. JAMA Pediatr 2019;173(5):e190025. http://dx.doi.org/10.1001/jamape diatrics.2019.0025.
- Nutten S. Atopic dermatitis: global epidemiology and risk factors. Ann Nutr Metab 2015;66 Suppl 1:8 – 16. http://dx.doi.org/10.1159/ 000370220.
- Hu LH, Huang X, You CJ, Li JX, Hong K, Li P, et al. Prevalence of overweight, obesity, abdominal obesity and obesity-related risk factors in southern China. PLoS One 2017;12(9):e0183934. http://dx.doi.org/ 10.1371/journal.pone.0183934.
- Sugiyama M, Arakawa H, Ozawa K, Mizuno T, Mochizuki H, Tokuyama K, et al. Early-life risk factors for occurrence of atopic dermatitis during the first year. Pediatrics 2007;119(3):e716 – 23. http://dx.doi.org/10.1542/peds.2006-0893.
- Ziyab AH, Ewart S, Lockett GA, Zhang H, Arshad H, Holloway JW, et al. Expression of the filaggrin gene in umbilical cord blood predicts eczema risk in infancy: a birth cohort study. Clin Exp Allergy 2017;47(9):1185 – 92. http://dx.doi.org/10.1111/cea.12956.
- 6. Gillman MW. Developmental origins of health and disease. N Engl J Med 2005;353(17):1848 – 50. http://dx.doi.org/10.1056/NEJMe 058187.
- 7. Xu B, Pekkanen J, Järvelin MR. Prenatal factors and occurrence of rhinitis and eczema among offspring. Allergy 1999;54(8):829 36. http://dx.doi.org/10.1034/j.1398-9995.1999.00117.x.
- Global Health Data Exchange. Global burden of disease study 2019 (GBD 2019) data resources. http://ghdx.healthdata.org/gbd-results-tool. [2021-5-27].

¹ Division of Birth Cohort Study, Guangzhou Women and Children's Medical Center, Guangzhou Medical University, Guangzhou, Guangdong, China; ² Department of Women and Child Health Care and Provincial Key Clinical Specialty of Woman and Child Health, Guangzhou, Guangdong, China.

[&] Joint first authors.

Projection of Temperature-Related Excess Mortality by Integrating Population Adaptability Under Changing Climate — China, 2050s and 2080s

Zhiying Sun^{1,2,&}; Qing Wang^{1,&}; Chen Chen¹; Yang Yang³; Meilin Yan⁴; Hang Du¹; Kai Chen⁵; John S. Ji⁶; Tiantian Li^{1,#}

Summary

What is already known about this topic?

An increasing number of studies have projected temperature-related mortality, but few consider the change of population's adaptability to future temperature and mortality burden from cold and heat effects.

What is added by this report?

This study offers a comprehensive characterization of human adaptability and excess mortality burden of temperature across various regions of China.

What are the implications for public health practice?

The temperature-related excess mortality was projected to increase in the 2050s and decrease in the 2080s. Heat adaptability was projected to increase in the future, but along with the rising temperatures, the heatrelated excess mortality continuously rose, except for the low-speed rising scenario. Although the excess mortality of cold was projected to decrease in the nearer future, it might not keep declining in the long run, due to the decreasing cold-adaptability, which deserves more attention.

Rising temperatures due to changing climate is a major public health concern. There is a great need to better estimate the disease burden related to temperature in China, considering changing population adaptation. A two-stage analysis was used in this study to obtain effect-modifiers in temperaturemortality relationships in 105 counties of China, then 3 united scenarios were constructed, future curves were fitted, and the numbers of attributable deaths in the 2050s and 2080s were estimated. Compared with the baseline period, the future cold effects show an upward trend, and the heat effects downward, indicating adaptability to cold would reduce while to heat would increase. The future temperature-related excess mortality was projected to increase in the 2050s and decrease in the 2080s, and cold-related mortality had a similar trend; however, heat-related mortality generally showed a continuously rising trend. Developed areas had greater cold effects and faced an increase of heat effects, while developing regions faced different situations, indicating different mitigation measures were needed. The medium-speed scenario could be the most appropriate developing scenario for China in the future, providing important sustainable policy implications.

Increasing temperatures under a changing climate are one of the major public health concerns in the 21st century. According to the Fifth Report of the Intergovernmental Panel on Climate Change (2013), the future global temperature will increase by 0.3 °C-4.8 °C under the different representative concentration paths (RCPs) by 2100. In 2070–2099, the annual averaged temperature was projected to increase by 1.9 °C-3.3 °C in China (*I*). China may face a larger burden of disease from a warming climate in the near future (*2*).

Studies have shown that human adaptability and adaptation measures can greatly affect the health effects of temperature (3). The adaptability to heat has been well-studied and will probably increase according to these previous studies, but the adaptability to cold remains unclear, although it is critical in projecting the temperature-related mortality burden (3-4).Additionally, in recent years, many studies have established a matrix of shared socioeconomic pathways-representative concentration paths (SSP-RCPs) to represent future human adaptability to temperature (5). However, there is a certain relationship between SSPs and RCPs, and each RCP in aspects is corresponding with certain some socioeconomic development pathways, and it may be unreasonable to simply use the matrix (6).

To address these gaps, this report constructed three united scenarios by linking the social economic development and climate change scenarios and projected the future mortality burden caused by high and low temperature in China under each scenario.

This paper included 105 counties distributed over the 7 geographical regions of the mainland of China (Supplementary Figure S1 and Supplementary Table S1, available in http://weekly.chinacdc.cn/) and defined the baseline period as 2013-2017 and two future periods as 2050s (2041-2070) and 2080s (2071-2099) based on the literature. This report conducted the project through three main steps (Supplementary Figure S2, available in http://weekly. chinacdc.cn/). First, the report modeled the exposureresponse relationship between temperature and mortality in 105 counties through distributed lag nonlinear model (DLNM) and a meta-regression. Through the Wald test, Cochran Q test, and I² in the regression, the report determined the effect modifiers, including the population size, birth rate, mortality, gross domestic product (GDP), air conditioning possession rate, heating in winter, latitude, and provinces (Supplementary Tables S2-S3, available in http://weekly.chinacdc.cn/). Second, predicting the temperature-morality relationship curves in the 2050s and 2080s. Three united scenarios (low, medium, and high-speed scenarios) were established by integrating the effect-modifiers and based on the mapping relationship between SSPs and the RCPs for future birth rate. mortality. temperature, and gross GDP (Supplementary Tables S4–S6, Supplementary Material, available in http://weekly.chinacdc.cn/). All these analyses were carried out using the packages "dlnm" and "mvmeta" in R (version 3.3.2, R Foundation for Statistical Computing, Vienna, Austria).

Figure 1 and Supplementary Table S7 (available in http://weekly.chinacdc.cn/) respectively showed the curves and the quantitative results between temperature and mortality at the median of the 5 general circulation models (GCM) under different united scenarios. The future cold effects were projected to increase with time, but the heat effects would decrease with time. Among the three scenarios, the future cold effects and heat effects both would be the greatest under the high-speed scenario.

The excess mortality from temperature under all three scenarios was projected to generally increase in the 2050s and decrease in the 2080s compared with the baseline period (Figure 2 and Supplementary Figure S3, available in http://weekly.chinacdc.cn/). Cold-related mortality would increase in the 2050s and decrease in the 2080s under the low-speed scenario and decrease in both the 2050s and the 2080s under the medium- and high-speed scenarios. Heat-related mortality had different trends: decreasing in the lowspeed scenario, and increasing in the medium- and the high-speed scenarios. Using the mid-level IPSL model and the medium-speed scenario as an example, the excess mortality from cold-and-net effects of temperature were projected to have minor changes (decrease by 5.7% and increase by 5.3%, respectively) in the 2050s and decrease by 81.7% and 46.6% in the 2080s, compared with the baseline period. The excess mortality from heat was projected to increase by 62.7% and 138.0% in the 2050s and 2080s, respectively. Taken together, the medium speed scenario was estimated to have the least temperature-related excess (Supplementary Table S8, mortality available in



FIGURE 1. Future relationships between temperature and mortality in three periods (baseline, 2050s, and 2080s) in China under 3 united scenarios. (A) The low-speed scenario; (B) The medium-speed scenario; (C) The highspeed scenario.

698

http://weekly.chinacdc.cn/). The number of coldrelated mortality was generally larger than the heatrelated excess mortality, except for the numbers in the 2080s under the medium and high-speed scenarios.

The temperature-related excess mortality would increase in the 2050s and decline in the 2080s (the East, the North, and the Central) or keep decreasing (Northeast, Northwest, and Southwest), and all the regions have the temperature-related excess mortality decreasing at last, except for South China, where it shows a rising trend (Figure 3, Supplementary Figure S4, and Supplementary Table S9, available in http://weekly.chinacdc.cn/).

DISCUSSION

This report offers a comprehensive characterization

of human adaptability and excess mortality burden of temperature across various regions of China in three future united scenarios, which fully considered the mapping relationships between the demographic characteristics of China and the SSPs, which provide more realistic estimates than previous studies.

The finding of an increase in heat adaptability is consistent with numerous previous studies (7-9), which may be caused by changes or differences in human physiological mechanism adjustment (3), socioeconomic development, the usage rate of air conditioning, and early warning systems (10-11). However, our study also indicated a declining trend in cold adaptability, which has not been reported before. Along with global warming, heat adaptability is increasing, and at the same time, cold adaptability may decrease due to reduced exposure to cold environments (6).



FIGURE 2. Changes (%) in projected annual death number caused by temperature in 3 periods (baseline, 2050s, and 2080s) in China under three united scenarios. (A) Net effect under low-speed scenario; (B) Net effect under medium-speed scenario; (C) Net effect under high-speed scenario; (D) Cold effect under low-speed scenario in China; (E) Cold effect under medium-speed scenario; (F) Cold effect under high-speed scenario in China; (G) Heat-effect under low-speed scenario; (H) Heat-effect under medium-speed scenario; (I) Heat-effect under high-speed scenario.

Abbreviations: GCM=general circulation model; GFDL=GFDL-ESM2M; HAD=HadGEM2-ES; MIROC=MIROC-ESM-CHEM; NOR=NorESM1-M; IPSL=IPSL-CM5A-LR.

China CDC Weekly



FIGURE 3. Changes (%) in temperature-related annual death number in seven regions of China in 3 periods (baseline, 2050s, and 2080s) under 3 united scenarios. (A) The cold-related mortality burden under the low-speed scenario; (B) The heat-related mortality burden under the low-speed scenario; (C) The temperature-related mortality burden under the low-speed scenario; (D) The cold-related mortality burden under the medium-speed scenario; (E) The heat-related mortality burden under the medium-speed scenario; (G) The cold-related mortality burden under the high-speed scenario; (H) The heat-related mortality burden under the high-speed scenario; (I) The temperature-related mortality burden under the high-speed scenario; (I) The temperature-related mortality burden under the high-speed scenario; (I) The temperature-related mortality burden under the high-speed scenario;

The report also found a generally increasing trend of heat-related excess mortality, and the cold-related and the total excess mortality were generally increasing in the 2050s and followed by a more obvious decrease in the 2080s. The trend is inconsistent with previous studies in the US, Europe, and the Republic of Korea (5,12). The inconsistency may be due to the differences in the sets of adaptation scenarios. Gosling et al. found that the adaptive modeling is a key part of future temperature-related mortality risk projection studies (3-4). Compared with previous studies, this report introduced more socioeconomic variables as adaptation indicators that may modify the temperature-mortality relationship, and the report fully considered the mapping relationship between birth rate, mortality, and SSP, and constructed three united scenarios instead of a simple matrix of the SSPs and RCPs.

There were differences in the changing trends of the

temperature-related excess mortality in different geographical regions of China under different united scenarios, which may be caused by both temperature and socioeconomic differences. First, the northwestern, southwestern, and northeastern regions have relatively lower temperatures, but the temperature will rise along with global warming, more attention should be paid to the disease burden caused by high temperatures in the future. Second, Central China, South China, North China, and East China generally had higher development levels, better medical resources, and better resilience to health risks from temperature changes. In these regions, it is worth paying attention to both the high and low temperatures in the 2050s, and more attention should be paid to the impact of heat in the 2080s. South China should prioritize responding to the health risk associated with temperatures, as it is the only region in China that has the temperature-related mortality increasing in all three

700

scenarios.

This study was subject to some limitations. First, the estimation relied heavily on future projection data, which brought some uncertainties. Second, this projection did not consider the change of population age structure, so the future mortality burden due to high and low temperature might be underestimated as China is experiencing a stage of population aging and the elderly are more vulnerable to non-optimal temperatures. Future studies should pay attention to these aspects and provide more insights for policymaking.

In summary, the findings of this report suggest that the temperature-related excess mortality was projected to increase in the 2050s and decrease in the 2080s. Heat adaptability was projected to increase in the future, but along with rising temperatures, the heatrelated excess mortality showed a continuously rising trend, except for low-speed scenarios; although the mortality burden due to the cold was projected to decrease in the nearer future, it might not keep declining in the long run due to the decreasing coldadaptability, which deserves more attention. Different regions would need different adaptation policies according to the patterns of temperature-related health risk and considering the differences in geographic, climate, demographic, and economic characteristics.

Funding: The Special Foundation of Basic Science and Technology Resources Survey of Ministry of Science and Technology of China (Grant No. 2017FY101204) and National High-level Talents Special Support Plan of China for Young Talents.. Research Center, Duke Kunshan University, Durham, NC, USA. [&] Joint first authors.

Submitted: April 14, 2021; Accepted: August 12, 2021

REFERENCES

- Wang L, Chen W. A CMIP5 multimodel projection of future temperature, precipitation, and climatological drought in China. Int J Climatol 2014;34(6):2059 – 78. http://dx.doi.org/10.1002/joc.3822.
- Climate Change Center of China Meteorological Administration. China blue book on climate change (2019). Beijing: Climate Change Center of China Meteorological Administration; 2019. http://www. cma.gov.cn/root7/auto13139/201905/t20190524_525556.html. (In Chinese).
- Gosling SN, Hondula DM, Bunker A, Ibarreta D, Liu JG, Zhang XX, et al. Adaptation to climate change: a comparative analysis of modeling methods for heat-related mortality. Environ Health Perspect 2017;125(8):087008. http://dx.doi.org/10.1289/EHP634.
- Kinney PL, O'Neill MS, Bell ML, Schwartz J. Approaches for estimating effects of climate change on heat-related deaths: challenges and opportunities. Environ Sci Policy 2008;11(1):87 – 96. http://dx. doi.org/10.1016/j.envsci.2007.08.001.
- Sanderson M, Arbuthnott K, Kovats S, Hajat S, Falloon P. The use of climate information to estimate future mortality from high ambient temperature: a systematic literature review. PLoS One 2017; 12(7):e0180369. http://dx.doi.org/10.1371/journal.pone.0180369.
- Zhang J, Cao LG, Li XC, Zhan MJ, Jiang T. Advances in shared socioeconomic pathways in IPCC AR5. Progr Inquisit Mutat Climatis 2013;9(3):225 – 8. http://dx.doi.org/10.3969/j.issn.1673-1719.2013. 03.012. (In Chinese).
- Li YX, Li GX, Zeng Q, Liang FC, Pan XC. Projecting temperaturerelated years of life lost under different climate change scenarios in one temperate megacity, China. Environ Pollut 2018;233:1068 – 75. http://dx.doi.org/10.1016/j.envpol.2017.10.008.
- Bobb JF, Peng RD, Bell ML, Dominici F. Heat-related mortality and adaptation to heat in the United States. Environ Health Perspect 2014;122(8):811 – 6. http://dx.doi.org/10.1289/ehp.1307392.
- Jenkins K, Hall J, Glenis V, Kilsby C, McCarthy M, Goodess C, et al. Probabilistic spatial risk assessment of heat impacts and adaptations for London. Climatic Change 2014;124(1):105 – 17. http://dx.doi.org/10. 1007/s10584-014-1105-4.
- Hajat S, Vardoulakis S, Heaviside C, Eggen B. Climate change effects on human health: projections of temperature-related mortality for the UK during the 2020s, 2050s and 2080s. J Epidemiol Community Health 2014;68(7):641 – 8. http://dx.doi.org/10.1136/jech-2013-202449.
- Li TT, Horton RM, Kinney PL. Projections of seasonal patterns in temperature- related deaths for Manhattan, New York. Nat Climate Change 2013;3:717 – 21. http://dx.doi.org/10.1038/nclimate1902.
- Huang CR, Barnett AG, Wang XM, Vaneckova P, FitzGerald G, Tong SL. Projecting future heat-related mortality under climate change scenarios: a systematic review. Environ Health Perspect 2011;119 (12):1681 – 90. http://dx.doi.org/10.1289/ehp.1103456.

doi: 10.46234/ccdcw2021.174

[#] Corresponding author: Tiantian Li, litiantian@nieh.chinacdc.cn.

¹ China CDC Key Laboratory of Environment and Population Health, National Institute of Environmental Health, Chinese Center for Disease Control and Prevention, Beijing, China; ² Institute of Environment and Health, Tianjin Center for Disease Control and Prevention, Tianjin, China; ³ Institute of Urban Meteorology, China Meteorological Administration, Beijing, China; ⁴ School of Ecology and Environment, Beijing Technology and Business University, Beijing, China; ⁵ Department of Environmental Health Sciences, Yale School of Public Health, New Haven, CT, USA; ⁶ Environmental

SUPPLEMENTARY MATERIAL

Data Sources

The daily temperature data are from the China Meteorological Data Network (http://data.cma.cn/), including the daily average temperature, maximum temperature, and minimum temperature of the counties in 2013–2017. We obtained the daily death number of non-accidental total mortality (International Classification of Diseases 10: A00-R99). The socioeconomic data are from the Sixth Population Census in 2010, including total population, birth rate, natural growth rate, mortality, male population, female population, total population under 5 years old, total population above 65 years old, proportion of minority population, and nonagricultural population. The 2010 Gross Domestic Product (GDP) data of each county were calculated by the 1 km raster data provided by the Resource and Environmental Science Data Center of the Chinese Academy of Sciences (http://www.resdc.cn/). The normalized difference vegetation index data were downloaded from the Geospatial Data Cloud (http://www.gscloud.cn/), and we obtained the maximum monthly vegetation coverage index of each county in 2010. The county-level air conditioning possession rate data are collected from the database of the National Survey on Air Pollution and Population Health carried out by the National Institute of Environmental Health, China CDC. The latitude, province, and heating in winter of each county were obtained directly from the domestic websites.

The future daily temperature projections were obtained from five global-scale general circulation models (GCMs) implemented in the fifth phase of the Climate Model Intercomparison Project, including GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, MIROC-ESM-CHEM, and NorESM1-M under two representative concentration pathways (RCP4.5 and RCP8.5). The temperature projections from five GCMs were further bias-corrected to ensure long-term statistical agreement with observations by the Inter-Sectoral Impact Model Intercomparison Project. Using a bilinear interpolation method, the bias-corrected projection of daily temperature on a horizontal resolution of 0.5 °C×0.5 °C was downscaled to finer resolution (0.05 °C×0.05 °C) and then averaged over each county to obtain the daily temperature projection at the county level.

The future demographic data came from the IPCC's SSPs: SSP1 (sustainable development), SSP2 (moderate development), SSP3 (local or inconsistent development), SSP4 (unbalanced development), and SSP5 (conventional development).

The future birth rate and mortality data were from the United Nations (UN) Population Data Centre (website: https://population.un.org/wpp/Download/Standard/Mortality/), including the birth rate and mortality for nine models. The data are at the national level. We obtained the baseline year county-level birth rate and mortality rate from the sixth population census in 2010, and we obtained both rates for 2040 to 2100 based on the UN population datasets.

Methods

We included 105 counties distributed over the 7 geographical regions of the mainland of China and with varying climate conditions (Supplementary Figure S1 and Supplementary Table S1) and defined the baseline period as 2013–2017 and two future periods as 2050s (2041–2070) and 2080s (2071–2099) based on the literature. Based on the modifier list collected from the literature and on data availability, we collected baseline data and future scenario data, and then conducted the project through three main steps (Supplementary Figure S2).

Exploring effect modifiers between temperature and mortality. We determined the effect-modifiers between temperature and mortality from a two-stage time series analysis in 105 counties. In the first stage, we modeled the nonlinear and delayed exposure-lag response relationship between temperature and mortality with a distributed lag nonlinear model (DLNM), applying a cross-basis spline function with 14 days of lag. In the second stage, we performed a meta-regression based on the baseline exposure-response relationship between temperature and mortality. All the available socioeconomic factors and population data in the 105 counties were substituted into the model as a covariate for the univariate curve meta-regression and used as potential effect-modifiers. The Cochran Q test showed the significance of the meta-regression results (Supplementary Table S2). The I² showed the heterogeneity of the meta-regression model. We determined the effect modifiers considering by Wald test, Cochran

S1



SUPPLEMENTARY FIGURE S1. Distribution of the annual average temperature of 2013–2017 in 105 counties of China (°C).

SLIPPI EMENTARY	TARLES1 D	escribe of m	eteorological	and death	data in 105	counties of Chin	2013_2017
SUFFLEIVIENTART	TADLE ST. D	escribe or m	eleorological	anu ueatri	uala III 100	counties of Chil	ia, 2013–2017.

		•						
Item	Number of days	Mean	SD	Minimum	P25	P50	P75	Maximum
Daily death data							1	
Total	1,826	9.54	6.83	0	5.00	8.00	13.00	221.00
Male	1,826	5.43	4.10	0	2.00	5.00	8.00	121.00
Female	1,826	4.11	3.41	0	2.00	3.00	6.00	100.00
0–64 years	1,826	2.38	2.08	0	1.00	2.00	3.00	47.00
65–74 years	1,826	1.94	1.86	0	1.00	2.00	3.00	53.00
≥75	1,826	5.22	4.40	0	2.00	4.00	7.00	121.00
Daily Meteorological data								
Mean temperature (°C)	1,826	14.26	10.94	-29.5	6.70	15.90	23.10	36.50
Maximum temperature (°C)	1,826	19.50	10.97	-24.3	11.70	21.30	28.20	42.60
Minimum temperature (°C)	1,826	9.89	11.36	-34.6	2.10	11.40	19.00	32.40
Mean relative humidity (%)	1,826	64.84	18.93	4.00	52.00	67.00	79.00	100.00

Q test, and I^2 in the regression (Supplementary Table S3). All these analyses were carried out using the packages "dlnm" and "mymeta" in R.

Prediction of the temperature-morality relationship in the 2050s and 2080s. To predict the risk of temperaturerelated mortality in the future, we established the united scenarios by integrating the effect-modifiers determined by the above steps. The effect modifiers we selected are shown in Supplementary Table S3, including the population size, birth rate, mortality, GDP, air conditioning possession rate, heating in winter, latitude, and provinces. The heating in winter, latitude and province data remain constant in the projection. The SSPs are scenarios considering

China CDC Weekly



SUPPLEMENTARY FIGURE S2. Flow diagram of the Projection of Temperature-Related Excess Mortality by Integrating Population Adaptability under Changing Climate — China, 2050s-2080s.

Abbreviations: DLNM=distributed lag nonlinear model; GDP=gross domestic product.

many aspects, including economic development, population, environment, and others. We found that the future demographic data from SSPs can be correlated with temperature, population, birth rate, mortality, and GDP from RCPs (Supplementary Tables S4-S5). Therefore, we established a mapping relationship based on the SSPs and future temperature prediction from RCPs, birth rate, and mortality, which were obtained by referring to the future population development report from the United Nations. The future GDP data were taken from the GDP prediction data of China under each SSP in Jiang et al. 2017(1). Thus, we established future united scenarios based on the mapping relationship between SSPs and the RCPs for future temperature, birth rate, mortality, and GDP (Supplementary Tables S4–S5). Three united scenarios were established (Supplementary Table S6) and the future curve of temperature and mortality was estimated under each united scenario using three steps: 1) the future effect modifiers were input into the multivariate meta-regression model, which was established in the previous step, and the coefficient and variance of each county were obtained; 2) the coefficient and variance of the 105 counties were merged at the national level with the "mvmeta" package in R; and 3) based on the coefficient and variance at the national level after the merging stage, the curves of temperature and mortality were fitted in the different periods.

Projection of temperature-related mortality in the 2050s and 2080s. The future annual temperature-related mortality in 105 counties in the 2050s and 2080s was predicted under the three united scenarios. The number of heat-related excess mortalities was projected for days with daily temperatures higher than the MMT, and the number of cold-related excess mortalities was projected for days with daily temperatures lower than the minimum mortality temperature (MMT). The excess mortality from the net effect of temperature was defined as the sum of heat-related excess mortality and cold-related excess mortality. We estimated the attribute fraction (AF) by Formula A; the number of daily excess mortalities attributable to temperature (or cold or heat, the same below) (\triangle *Mortality*) were calculated by Formula B, and we calculated the average number of annual temperature-related mortalities in each county. In the formulas, the *i* represents the county; RR_i is the relative mortality risk of this temperature at



SUPPLEMENTARY FIGURE S3. Change trends of temperature-related annual deaths of different GCMs in 3 periods (baseline, 2050s, and 2080s) in China under 3 united scenarios. (A) Net effect under the low-speed scenario; (B) Net effect under the medium-speed scenario; (C) Net effect under the high-speed scenario; (D) Cold effect under the low-speed scenario; (E) Cold effect under the medium-speed scenario; (F) Cold effect under the high-speed scenario; (G) Heat effect under the low-speed scenario; (I) Heat effect under the high-speed scenari

Abbreviations: GCMs=general circulation models; GFDL=GFDL-ESM2M; HAD=HadGEM2-ES; MIROC=MIROC-ESM-CHEM; NOR=NorESM1-M; IPSL=IPSL-CM5A-LR.

county *i* compared with MMT, which is obtained from the future exposure-response relationship curve; POP_i is the future population of county *i*; Y_{0i} is the future mortality rate of county *i*; and $\triangle Mortality$ is the number of deaths due to temperature in county *i*. The effect indicator is the number of temperature-related annual mortality due to climate change compared with the number in the baseline period.

$$AF_i = \left(RR_i - 1\right) / RR_i \times 100 \tag{1}$$

$$\Delta Mortality = POP_i \times Y_{0i} \times AF_i \tag{2}$$

We also divided the 105 counties into seven groups according to the seven major sub-regions of China (North China, East China, South China, Central China, Northeast China, Northwest China, and Southwest China) and projected their future excess mortality related to cold, heat, and net effects of temperature.

China CDC Weekly



SUPPLEMENTARY FIGURE S4. Change trends of temperature-related annual deaths in 7 regions in 3 periods (baseline,2050s, and 2080s) in China under 3 united scenarios. (A) Net effect under the low-speed scenario; (B) Net effect under the medium-speed scenario; (C) Net effect under the high-speed scenario; (D) Cold effect under the low-speed scenario; (E) Cold effect under the medium-speed scenario; (F) Cold effect under the high-speed scenario; (G) Heat effect under the low-speed scenario; (I) Heat effect under the high-speed scenario.

SUPPLEMENTARY TABLE S2. Sensitivity analysis of the relationship between temperature and mortality of 105 counties in China, 2013–2017.

Sensitivity analysis	l ²	Q (<i>P</i>)
Core model	46.8%	977.43 (<i>P</i> <0.05)
Add PM _{2.5}	46.8%	993.10 (<i>P</i> <0.05)
Change degree of time		
Time/df=6	48.8%	1,016.36 (<i>P</i> <0.05)
Time/df=5	52.2%	1,087.91 (<i>P</i> <0.05)
Add relative humidity		
+ ns (rh/df=3)	46.9%	979.69 (<i>P</i> <0.05)
+ ns (rh/df=5)	46.8%	977.82 (<i>P</i> <0.05)

Factors	²	Q(<i>P</i>)
1	39.70%	838.33 (<i>P</i> <0.05)
The total population	39.40%	842.14 (<i>P</i> <0.05)
Birth rate	38.10%	823.47 (<i>P</i> <0.05)
Mortality	38.20%	825.33 (<i>P</i> <0.05)
GDP	38.70%	832.03 (<i>P</i> <0.05)
Air-conditioning ownership	37.40%	813.23 (<i>P</i> <0.05)
Heating	35.40%	789.22 (<i>P</i> <0.05)
Latitude	36.00%	796.27 (<i>P</i> <0.05)
Province	38.90%	834.68 (<i>P</i> <0.05)

Note: "/"=meta-regression without adding any factors.

Abbreviations: GDP=gross domestic product

SUPPLEMENTARY TABLE S4. Correlation between Shared Socio-economic Pathways (SSP) and representative concentration paths (RCP).

SSP	RCP
SSP1	4.5
SSP2	6.0
SSP3	8.5
SSP4	8.5
SSP5	1

Source: Zhang J, Cao LG, Li XC, Zhan MJ, Jiang T. Advances in shared socio-economic pathways in IPCC AR5. Advances in Climate Change Research, IPCC AR5. Advances in Climate Change Research 2013;9(3):225–8. http://www.climatechange.cn/EN/Y2013/V9/I3/225.

|--|

		-	
SSP	Birth rate	Mortality	Education level
SSP1	Low	Low	Rapid development
SSP2	Medium	Medium	Global convergence
SSP3	High	High	Constant enrollment rate
SSP4	Medium	Medium	Constant enrollment rate
SSP5	Low	Low	Rapid development

Source: Zhang J, Cao LG, Li XC, Zhan MJ, Jiang T. Advances in shared socio-economic pathways in IPCC AR5. Advances in Climate Change Research 2013;9(3):225-8. http://www.climatechange.cn/EN/Y2013/V9/I3/225.

SUPPLEMENTARY T	ABLE S6.	Future	united	scenario	settings*
-----------------	----------	--------	--------	----------	-----------

United Scenarios	Low-speed scenario	Medium-speed scenario	High-speed scenario
Temperature	RCP8.5, 5GCMs	RCP8.5, 5GCMs	RCP4.5, 5GCMs
Population	SSP3	SSP4	SSP1
Birth rate	High	Medium	Low
Mortality	High	Medium	Low
GDP	2050s and 2080s increase by 410% and 420%, respectively	2050s and 2080s increase by 570% and 500%, respectively	2050s and 2080s increase by 660% and 680%, respectively
Air conditioning possession rate	2050s and 2080s increase by 50% and 100%, respectively	2050s and 2080s increase by 100% and 150%, respectively	2050s and 2080s increase by 150% and 200%, respectively

* The three colors represent low, medium, and high levels from light to dark, respectively.

Abbreviations: SSP=shared socioeconomic pathways; RCP=representative concentration pathways.

Periods	Scenarios	Heat effects-RR (95% CI) 32 °C (99%) vs. MMT (%)	Cold effect-RR (95% Cl) −15 °C (1%) <i>vs.</i> MMT (%)	MMT (°C)
Baseline period	1	17.09 (14.99, 9.23)	12.04 (9.81, 14.31)	23.8
	Low-speed	6.36 (5.33, 7.41)	28.16 (23.65, 32.85)	25.6
2050s	Medium-speed	6.77 (5.61, 7.95)	38.58 (32.14, 45.34)	25.4
	High-speed	7.36 (6.13, 8.60)	39.39 (32.15, 47.04)	25.5
	Low-speed	6.47 (5.25, 7.69)	34.60 (29.55, 39.87)	24.6
2080s	Medium-speed	6.77 (5.67, 7.89)	42.13 (35.28, 49.32)	25.5
	High-speed	6.35 (5.15, 7.57)	47.17 (38.17, 56.75)	25.4

SUPPLEMENTARY TABLE S7	. The heat and cold effects in di	fferent scenarios and periods in China.
------------------------	-----------------------------------	---

Note: "/"=No scenarios in the baseline period.

Abbreviation: CI=confidence interval; MMT=the minimum mortality temperature.

SUPPLEMENTARY TABLE S8. Future temperature-related annual death number with 5 GCMs in 3 periods (baseline, 2050s, and 2080s) in China under 3 united scenarios (the low, medium, and high-speed scenarios).

GCM	(95%CI)						
	(337/01)	Low-speed (95%CI)	Medium-speed (95%Cl)	High-speed (95%Cl)	Low-speed (95%Cl)	Medium-speed (95%Cl)	High-speed (95%Cl)
Temperature-	-related annual dea	ath					
GFDL	18,178 (14,716-21,592)	26,791 (19,725-33,726)	24,961 (16,850-32,905)	28,219 (16,391-39,765)	23,580 (17,993–29,060)	12,594 (7,414-17672)	15,629 (5,597-25,404)
HAD	18,178 (14 716-21 592)	23,057	19,740 (11 876–27 451)	21,944	15,953 (10,852–20,967)	11,922 (6.650–17.090)	13,787 (3 921–23 415)
MIROC	18,178	22,945	17,663	19,341	16,286 (11,176-21,306)	9,499	12,393
NOR	18,178	25,522	21,057	23,195	18,511	9,851	(3,009–21,301) 11,619
IPSI	(14,716-21,592) 18,178	(18,559-32,357) 23,308	(13,083-28,870) 19,136	(11,669-34,456) 21,211	(13,216-23,709) 16,808	(4,802-14,805) 9,707	(1,719–21,275) 12,456
	(14,716-21,592)	(16,596-29,899)	(11,481–26,642)	(10,143-32,034)	(11,721–21,805)	(4,740–14,582)	(2,934–21,752)
Colu-leialeu a		05 405	00 704	04.000	00.050	10.001	11.000
GFDL	15,271 (12,224–18,275)	25,125 (18,428-31,692)	(15,135-30,102)	24,909 (13,892-35,651)	22,858 (17,483-28,128)	(5,712-14,833)	(2,897-20,472)
HAD	15,271 (12,224–18,275)	19,365 (13,194–25,420)	13,604 (6,831–20,235)	13,251 (3,459–22,810)	12,977 (8,516–17,357)	5,062 (784-9,250)	3 (-7,989–7,782)
MIROC	15,271 (12,224-18,275)	19,938 (13,808-25,953)	12,076 (5,618-18,400)	11,378 (2,031-20,507)	13,619 (9,095-18,060)	1,554 (-2,262-5,293)	-1,042 (-8,570-6,293)
NOR	15,271 (12 224-18 275)	23,568	18,009 (10 739-25 123)	18,750 (8 259-28 987)	17,187	5,924 (1 744-10 018)	5,012 (-3 417-13 213)
IPSL	(12,224-19,275)	20,650	14,408	14,413	14,850	2,791	797
Heat-related :	(12,224 - 10,273)	(14,510-20,074)	(7,719-20,950)	(4,700-23,003)	(10,231-19,303)	(-1,139-0,041)	(-0,994-0,505)
	2 006	1 667	2 261	2 210	700	2 272	2 021
GFDL	2,900 (2,491-3,397)	(1,297-2,034)	(1,715-2,803)	(2,499-4,115)	(510-932)	(1,701-2,840)	(2,700-4932)
HAD	2,906 (2,491–3,397)	3,092 (3,011–4,366)	(5,045-7,216)	0,093 (7,164-10,205)	(2,336-3,610)	(5,867-7,840)	(11,910-15,634)
MIROC	2,906 (2.491-3.397)	3,007 (2.431-3.578)	5,587 (4.510-6.654)	7,962 (6.457-9.453)	2,667 (2.082-3.247)	7,946 (6.863-9.016)	13,435 (11.639–15.208)
NOR	2,906	1,953	3,048	4,444	1,323	3,927	6,606
IPSI	2,906	2,657	(2,344 ⁻ 3,747) 4,728	(3,411-3,409) 6,798	1,958	(3,030 ⁻⁴ ,787) 6,915	11,658
	(2,491-3,397)	(2,086-3,225)	(3,762-5,687)	(5,435-8,149)	(1,470-2,442)	(5,879-7,941)	(9,928-13,369)

NOR=NorESM1-M; IPSL=IPSL-CM5A-LR..

S7

	Baseline period		2050s		1	2080s	
Regions	(95%CI)	Low-speed (95%Cl)	Medium-speed (95%Cl)	High-speed (95%Cl)	Low-speed (95%Cl)	Medium-speed (95%Cl)	High-speed (95%Cl)
Temperature-	related annual dea	ath					
Northoast	3,601	3,008	3,004	3,647	2,380	1,419	1,783
North	(2963-4,229) 1,872	(2,348-3,653) 3,062	(2,211-3,776) 2,613	(2,488-4,770) 2,784	(1,880-2,869) 2,305	(899-1,925) 1,132	(730-2,802) 997
	(1,528-2,212) 6,476	(2,218-3,889) 11,400	(1,642-3,562) 9,601	(1,403-4,128) 10,230	(1,685-2,912) 8,683	(488-1,762) 5,256	(-290-2,247) 6,378
East	(5,252-7684) 516	(7,982-14,758) 738	(5,542-13,584) 843	(4,422-15,915) 1 049	(5,996-11,323) 520	(2,599-7,866) 706	(1,342-11,304) 1 223
South	(398-632)	(541-933)	(593-1,090)	(718–1,376) 2 191	(368-670)	(529-880)	(917-1,525)
Central	(1,443-2,118)	(1,600-2,851)	(1,149-2,519)	(1,130-3,230)	(1,110-2,046)	(705-1,596)	(817-2,473)
Northwest	(1,771-2,601)	(1,431-2,474)	(867-1,883)	(777-2,361)	(1,071-1,835)	(182-789)	(-232-991)
Southwest	(1,362-2,116)	1,928 (1,346-2,501)	(680-1,772)	1,303 (524–2,066)	1,300 (880–1,714)	559 (239–873)	753 (166-1,328)
Cold-related a	annual death						
Northeast	3,538 (2.915-4152)	2,990 (2.337-3.629)	2,942 (2.169-3.694)	3,555 (2.426-4.649)	2,361 (1.869-2.841)	1296 (805-1773)	1576 (575-2542)
North	1,689 (1.375-1.999)	2,957 (2.140-3.758)	2,406 (1.486-3.304)	2,495 (1.186-3.770)	2,227 (1.631-2.811)	811 (230–1379)	444 (-732-1584)
Faat	4,912	9,900	7,029	6,533	7,553	1900	444
East	(3,900-5,910) 257	(6,796-12,946) 430	(3,495-10,491) 305	(1,473-11,478) 301	(5,141-9,921) 284	(-213-3972) 98	(-3637-4424) 151
South	(181-333) 1 326	(295-563)	(158-449)	(112-487)	(186-380)	(18,177)	(12,288)
Central	(1,048-1,600)	(1,174-2,246)	(537-1,652)	(241-1,968)	(822-1,611)	(-30-618)	(-502-730)
Northwest	2,091 (1,690-2,487)	1,950 (1,425-2,464)	(854–1,859)	(756-2,323)	1,451 (1,068–1,827)	454 (156-746)	329 (-277–916)
Southwest	1,458 (1,116-1,795)	1,788 (1,233-2,334)	1,016 (509-1,515)	991 (275-1,693)	1,203 (805-1,593)	275 (2-543)	251 (-253-745)
Heat-related a	annual death						
Northoast	62	18	62	92	20	123	207
Normeast	(47-77) 183	(11-25) 105	(41-82) 207	(62-121) 288	(11-28) 78	(94-152) .321	(155-260) 553
North	(153-213)	(78-131)	(156-258)	(217-359)	(55-101)	(258-383)	(442-664)
East	1,564 (1,351–1,775)	1,500 (1,186-1,812)	2,572 (2,047-3,093)	3,697 (2,949–4,437)	1,129 (855–1,401)	3,356 (2,812-3,895)	5,934 (4,978-6,879)
South	259 (218–299)	308 (246-370)	539 (435-642)	748 (606–889)	236 (182-290)	607 (511-702)	1,072 (905–1 237)
Central	457	516	740	1,077	362	858	1,532
	(395-518) gr	(420-605) 8	(012-867) 19	(889-1,262) 29	(289-435) 6	(135-918) 35	(1,319-1,743) 60
Northwest	(82-115)	(5-10)	(13-24)	(21-38)	(4-8)	(27-43)	(45-75)
Southwest	284 (246–321)	140 (113-167)	214 (171-257)	311 (249–373)	98´ (75–120)	284 (237-330)	501 (419–583)

SUPPLEMENTARY TABLE S9. Future temperature-related annual deaths in 3 periods (baseline, 2050s and 2080s) in 7 regions of China under 3 united scenarios (the low, medium, and high-speed scenarios).

REFERENCES

1. Jiang T, Zhao J, Jing C, Cao LG, Wang YJ, Sun HM, et al. National and Provincial Population Projected to 2100 Under the Shared Socioeconomic Pathways in China. Climate Change Research 2017;13(2):128–137. http://www.climatechange.cn/EN/10.12006/j.issn.1673-1719.2016.249.

Norovirus Detection in Environmental Samples from Norovirus Outbreaks in Schools and Kindergartens — Beijing Municipality, China, October–December 2020

Baiwei Liu¹; Yu Wang²; Lei Jia²; Yi Tian²; Xiaoli Wang²; Shuaibing Dong²; Lingyu Shen²; Zhiyong Gao^{1,#}; Quanyi Wang^{2,#}

Summary

What is already known on this topic?

The norovirus has often caused outbreaks in schools and kindergartens, but minimal research has been performed on environmental contamination during norovirus outbreaks in schools and kindergartens.

What is added by this report?

This report conveys the norovirus detection rates and viral loads in different environmental sites in 45 norovirus outbreaks in Beijing Municipality from October to December 2020.

What are the implications for public health practice?

The evidence presented here can instruct professionals and the public to sample and disinfect key locations of the environment purposefully when responding to norovirus outbreaks.

Norovirus is the main pathogen responsible for sporadic cases and outbreaks of acute gastroenteritis worldwide (1), and it often causes outbreaks in schools and kindergartens (2-3). Contact with a contaminated environment is the main transmission mode of this virus, but relatively few studies focus on environmental contamination during norovirus outbreaks across a large number of schools and kindergartens (4-6). This study included 45 norovirus outbreaks in schools and kindergartens with environmental positive specimen in Beijing from October to December 2020, among which 44 outbreaks were caused by person-to-person transmission. The environmental detection rate of norovirus was 17.54% in these 44 outbreaks, in the residence of key patients (including initial patients and index patients), the highest norovirus detection rate was found from housewares (e.g., toys, TV remotes, and desk lamps) at 31.25%, and the lowest cycle threshold (Ct) value was found in a door handle sample at 19.59. In the school buildings, the highest norovirus detection rate was found in the lavatory and

flush button samples (26.79%), and the lowest Ct value (18.65) was found in a stair handrail sample. These locations are most likely to be contaminated by the virus during norovirus outbreaks, and it is necessary to clean and disinfect these key locations purposefully.

The epidemiological investigation of norovirus outbreaks in schools and kindergartens was conducted in Beijing from October to December 2020. A swab dipped in the solution from a virus sampling tube was smeared on the environmental surface. The sampling locations included the residence of key patients, school buildings, and school canteens. The sampling sites included lavatory and flush buttons, door handles, housewares, cleaning tools, and related items. Noroviruses were detected and genotyped using the real time reverse transcription polymerase chain reaction detection kit (Bioperfectus Ltd., Taizhou, China) according to the manufacturer's protocol. Statistical analyses were performed using SPSS software (version 19.0, IBM, Chicago, IL, USA). Chi-squared tests were used to compare the norovirus detection rates from different sites, and the Kruskal-Wallis H-test was used to compare the median Ct values from different sites; P-values of <0.05 were considered to indicate statistical significance.

Environmental samples were collected in all norovirus outbreaks in schools and kindergartens, among which these 45 outbreaks had positive environmental samples. The median number of individuals affected per outbreak was 9 [interquartile range (IQR): 5–16]. The most common transmission mode was person-to-person (97.78%, 44/45), and food-borne transmission occurred in 1 outbreak. Only 1 outbreak was caused by genogroup I noroviruses, and the other 44 outbreaks were caused by genogroup II noroviruses.

A total of 707 environmental samples were collected from the 44 norovirus outbreaks with person-to-person transmission. For these, the total norovirus detection rate was 17.54% (124/707), with a 22.41% (65/290) detection rate for samples from the residence of key patients and a 17.88% (59/330) detection rate for samples from the school buildings, norovirus was not detected in samples from the school canteens, a statistical difference was found between these detection rates (χ^2 =238.095, P<0.001) and the pair-to-pair comparison showed that there was no significant difference between the norovirus detection rates for samples from the school buildings and from the residence of key patients (χ^2 =1.984, P=0.159). In the residence of key patients, the 3 sites with the highest norovirus detection rates were housewares (31.25%), lavatory and flush buttons (30.00%), and desktops and floors (28.57%). In the school buildings, these sites were lavatory and flush buttons (26.79%), washing facilities (19.61%), and desktops and floors (19.57%) (Table 1). In the food-borne transmission outbreak, a total of 83 environmental samples were collected from the school canteen and staff dormitory. Only 1 sample was norovirus-positive (from the door handle of the kitchen staff dormitory; Ct value: 39.49), yielding a norovirus detection rate of 1.20%.

Ct values were obtained for 102 norovirus positive samples. Regarding samples from the residence of key patients, the lowest Ct value (19.59) was found in a door handle sample. Of the median Ct values in 8 sites, the lowest one was door handles (32.09, IQR: 30.78–36.03), and there was no statistical difference among the median of these Ct values (χ^2 =7.698, *P*=0.360) (Figure 1). Regarding samples from school buildings, the lowest Ct value (18.65) was found in a stair handrail sample. Of the median Ct values in 7 sites, the lowest one was lavatory and flush buttons (34.18, IQR: 33.02–37.07), and there was no statistical difference among the median of these Ct values (χ^2 =1.503, *P*=0.959) (Figure 2).

DISCUSSION

Our results showed that a high-level of environmental contamination occurred during norovirus outbreaks in schools and kindergartens in Beijing from October to December 2020. The highest norovirus detection rate was found from the housewares in the residence of key patients, and the highest norovirus detection rate was found from the lavatory and surrounding environments in the school buildings. The sample from door handle and stair handrail had the lowest Ct values in the residence of key patients and the school buildings, respectively.

TABLE 1. Norovirus detection rates at different environmental sites in schools and kindergartens in Beijing, October–December 2020.

Sampling site	Sampling number	Positive number (%)
Residence of key patients	290	65(22.41%)
Housewares*	32	10(31.25%)
Lavatory and flush buttons	60	18(30.00%)
Desktops and floors	14	4(28.57%)
Cleaning tools and drains [†]	42	9(21.43%)
Kitchen utensils§	41	8(19.51%)
Faucet handles	39	7(17.95%)
Door handles	47	8(17.02%)
Water cups and tablewares	15	1(6.67%)
School buildings	330	59(17.88%)
Lavatory and flush buttons	56	15(26.79%)
Washing facilities [¶]	51	10(19.61%)
Desktops and floors	46	9(19.57%)
Handles and handrails	62	10(16.13%)
Housewares	44	7(15.91%)
Cleaning tools and drains	53	7(13.21%)
Drinking water facilities**	18	1(5.56%)
School canteens	87	0(0%)
Dining car and dining environment	4	0(0%)
Handles	13	0(0%)
Lavatory	8	0(0%)
Cleaning tools and drains	21	0(0%)
Food processing tools ^{††}	24	0(0%)
Cleaning facilities	17	0(0%)
Total	707	124(17.54%)

* Housewares included toys, remote controls, towels, beds, chairs, washing machines, lamps, and other related items.

[†] Cleaning tools and drains included brooms, dustpans, mops, rags, sewers, and other related items.

[§] Kitchen utensils included chopping boards, kitchen knives, washing bowls, and the refrigerator inner wall.

¹¹ Washing facilities included faucet handles, hand sanitizer buttons, wash basins, and other related items.

** Drinking water facilities in school buildings included water dispensers, hot buckets, and other related items.

^{††} Food processing tools included kitchen knives, chopping boards, cooking spoons, rolling pins, operating tables, and other related items.

Compared with environmental contamination of the school canteens, the locations that residence of key patients and the school buildings were more severe. The findings were similar to reports from norovirus outbreaks in houseboats in Arizona described by Jones et al. (7). This might be explained by the cleaning procedures of kitchen staff, helping to reduce



FIGURE 1. Ct values of norovirus at different environmental sites in the residence of key patients in Beijing, October–December 2020.



FIGURE 2. Ct values of norovirus at different environmental sites in school buildings in Beijing, October–December 2020.

environmental contamination in school canteens.

In the residence of key patients, the highest norovirus detection rate was found from housewares, and the second highest detection rate was found from lavatory and flush buttons. This may indicate that, in the residence of key patients, people do not pay as much attention to hand hygiene as they do outside, and their hands often touch the surfaces of objects increasing the range of contamination, at the same time the cleaning and disinfection of housewares surfaces are often ignored. Therefore, it is important not only to disinfect the lavatory and surrounding environments, but also to clean and disinfect housewares surfaces at home. When disinfecting different objects (such as textiles, hard surfaces, and toilets), different methods are suggested and chlorine disinfectants are priority when applicable. In school buildings, the highest norovirus positive detection rate was found from the lavatory and surrounding environments (e.g., flush button, sink faucet, and hand sanitizer button), which was consistent with the norovirus contamination results from two norovirus outbreaks in kindergartens in Jingmen City of Hubei Province (4). Norovirus is usually excreted in feces during norovirus outbreaks, which may lead to contamination of the lavatory environment in school and kindergarten.

The Ct value can reflect the severity of contamination, with lower Ct values representing higher viral loads and correspondingly more serious levels of environmental contamination. Among the samples collected from the residence of key patients and school buildings, those from door handles and stair handrails had the lowest Ct value, suggesting that both may be an important contributor to norovirus transmission. This finding was consistent with the results of Rico et al. (8), who evaluated the environmental contamination in norovirus outbreaks in the Barcelona region between January 2017 and March 2019, in which they found that norovirues were most frequently detected on toilet handles and handrail bars. Therefore, locations where the hands often touch, such as door handles and stair handrails should be disinfected regularly during norovirus outbreaks.

This study was subject to some limitations. First, some factors could affect detection rates and Ct values such as the level of virus shedding of the patients, the contact frequencies by the patients of the sites where the environmental samples were collected, and the sample collection process that could not include all contaminated sites. Second, some PCR inhibitors existed in the environments, which could have affected the test results. Third, Ct values of some positive sites were not reported, so there may be some bias. Further research, such as conducting gene sequencing of the noroviruses in environmental samples, estimating the duration of contamination, and evaluating the disinfection effect, is needed.

This article provided evidence describing the locations and environmental sites that were most likely to be contaminated by the virus during norovirus outbreaks. These results could instruct professionals and the public to sample and disinfect the environment properly, and it is helpful to formulate a sampling, cleaning and disinfection workflow for the disposal of norovirus outbreak.

Acknowledgments: District-level CDCs of Beijing Municipality.

Funding: Supported by the Capital's Fund for Health Improvement and Research (No. 2020–2–1011).

doi: 10.46234/ccdcw2021.165

[#] Corresponding authors: Zhiyong Gao, zhiyonggao1@163.com; Quanyi Wang, bjcdcxm@126.com.

¹ Beijing Research Center for Preventive Medicine, Beijing, China; ² Beijing Center for Disease Control and Prevention, Beijing, China.

Submitted: June 17, 2021; Accepted: July 27, 2021

REFERENCES

- Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson MA, Roy SL, et al. Foodborne illness acquired in the united states—major pathogens. Emerg Infect Dis 2011;17(1):7 – 15. http://dx.doi.org/10. 3201/eid1701.p11101.
- 2. Ran L. Prevention and control of acute gastroenteritis outbreaks caused

by norovirus. Int J Virol 2020;27(2):89 – 91. http://dx.doi.org/10.3760/ cma.j.issn.1673-4092.2020.02.001. (In Chinese).

- Havumaki J, Eisenberg JNS, Mattison CP, Lopman BA, Ortega-Sanchez IR, Hall AJ, et al. Immunologic and epidemiologic drivers of norovirus transmission in daycare and school outbreaks. Epidemiology 2021;32(3):351 – 9. http://dx.doi.org/10.1097/EDE.00000000000 1322.
- Chen TL, Deng XQ. Investigation of environmental sample virus contamination in the norovirus epidemic. Chin J Child Health Care 2018;26(8):921 – 3. http://dx.doi.org/10.11852/zgetbjzz2018-26-08-30. (In Chinese).
- Centers for Disease Control and Prevention (CDC). Norovirus outbreak in an elementary school--district of Columbia, February 2007. MMWR Morb Mortal Wkly Rep 2008;56(51–52):1340–3. https://pubmed. ncbi.nlm.nih.gov/18172420/.
- Zheng Y, Jia L, Liu BW, Gao ZY, Wang XL, Yan HQ, et al. Investigation on contamination by norovirus in hotels and tourist buses in Beijing. Int J Virol 2020;27(2):120 – 3. http://dx.doi.org/10.3760/ cma.j.issn.1673-4092.2020.02.008. (In Chinese).
- 7. Jones EL, Kramer A, Gaither M, Gerba CP. Role of fomite contamination during an outbreak of norovirus on houseboats. Int J Environ Health Res 2007;17(2):123 – 31. http://dx.doi.org/10.1080/ 09603120701219394.
- Rico E, Pérez C, Belver A, Sabaté S, Razquin E, De Benito J, et al. Norovirus detection in environmental samples in norovirus outbreaks in closed and semi-closed settings. J Hosp Infect 2020;105(1):3 – 9. http://dx.doi.org/10.1016/j.jhin.2020.02.011.

First Technical Specifications for Health Risk Assessment of Ambient Air Pollution in China

Jingxiu Han¹; Junrui Chang¹; Jingyi Liu¹; Congshen Meng¹; Dongqun Xu^{1,#}

The Global Burden of Disease study showed that air pollution is the fourth risk factor for attributable deaths (1) and a major public health problem in China. Therefore, the Chinese government has taken a series of measures to control air pollution. However, the attributable disease burden of air pollution can be effectively reduced only by integrating health into air pollution control policies. Health risk assessment comprehensively considered the impact of atmospheric pollution levels, pollutant toxicity, exposure-response coefficients, and the characteristics of exposed population. It may provide a scientific basis for formulating policies for air pollution prevention and control, revising standards of ambient air quality, and putting forward targeted measures for public health protection.

BACKGROUND

A network of air pollution and health impact monitoring was established in 2013 to cope with the impact of severe haze on the health of China's population (2). By 2019, the monitoring network had covered 164 counties in 84 cities in 31 provincial-level administrative divisions on the mainland of China to gather monitoring data on air quality and population health. This, therefore, provided a data basis for health risk assessment.

A comprehensive review of the published literature on health risk assessment found that the four-step evaluation procedure, which includes hazard identification, exposure-response assessment, exposure assessment, and risk characteristic analysis, are the basic framework for carrying out health risk assessments. There were some problems in the process of risk assessment, including poor data quality, blind use of models for assessment, opaque assessment process, lack of uncertainty analysis of assessment results, and incomplete information in risk assessment reports. Health risk assessment techniques need to be standardized to guide relevant staff to conduct the

assessment in a scientific, transparent, and consistent manner and to identify the main health hazards and potential health risks of urban air pollution.

Before 2019, the Ministry of Environmental Protection (Ministry of Ecology and Environment of the People's Republic of China) and the Ministry of Health (National Health Commission of the People's Republic of China) issued some technical guidelines for environmental risk assessment to protect ambient air quality, but there were no guidelines for health risk assessment to assess the health risk of air pollution (3). Therefore, there was an urgent need to develop technical specifications for health risk assessment of ambient air pollution in order to guide the local scientific use of monitoring data, to evaluate the current health effects and risks of atmospheric pollution in China, and to provide a scientific basis for effective intervention measures to reduce the health hazards caused by air pollution.

METHODS

First, the National Institute of Environmental Health of China CDC widely collected international technical documents and publications related to environmental health impact assessments and health risk assessments, including guides, specifications, assessment reports, and evaluation methods and tools. All of these were analyzed comprehensively to understand the characteristics and application scope of various health risk assessment methods and tools. It determined that the four-step evaluation was procedures were also followed in this specification, which was recognized by developed countries and international organizations. The four-steps included hazard identification, exposure-response assessment, exposure assessment, and risk characteristic analysis.

Second, the characteristics of the air pollutants and health data were analyzed by using the monitoring system data, which included not only data on the concentrations of air pollutants related to exposure but also data on causes of death, outpatient and emergency hospital visits, hospitalizations related to health, and meteorological data affecting air pollution and health outcomes. Aimed towards the problems emerging in previous risk assessments and drawing lessons from the standards and guides provided in recent years, the "Technical Specifications for Health Risk Assessment of Ambient Air Pollution" (WS/T 666-2019) was formulated to be people-oriented, scientific, feasible, and practical (4). The specifications included three parts: General Provisions, Health Risk Assessments of Populations Based on Demographic Data, and Health Risk Assessments of Populations Based on Toxicity Data of Air Pollutants. Sichuan CDC and Jiangsu CDC jointly participated in the development of the specification.

RATIONALE AND EVIDENCE

To fully use international research results, the guidelines for health impact assessments and health risk assessments issued by the World Health Organization (WHO) and the US Environmental Protection Agency (US EPA) were adjusted to fit the actual circumstances in China. The technical specifications (WS/T 666–2019) detail and expand relevant content and put forward data quality requirements based on the existing monitoring data in China. Two methods of health risk assessment were given to expand the scope of applications of risk assessments.

One method was based on demographic data, which mainly referenced relevant guidelines, methods, and tools developed by WHO (5-6). As for the assessment of the exposure-response relationship, two methods were given to obtain the coefficient. One was developed using existing literature, and the other was through the analysis of survey or monitoring data. This specification also provided methods for calculating the coefficient of the exposure-response curve. The coefficient obtained by either method for acute or chronic health effects should be selected accordingly, depending on the needs of the health risk assessment.

The other method was based on the concentration of contaminants and their toxicity, which mainly referenced the method recommended by the US EPA (7-11). Based on practical application considerations, the steps of assessing the exposure-response relationship in health risk assessments were defined as follows: obtaining the concentration data of air pollutants, obtaining the exposure parameters of population, consulting the toxicological data of pollutants. determining and the screening concentrations. Screening concentrations were concentrations of health threshold effects of carcinogenic and non-carcinogenic air pollutants selected under specific exposure conditions. If the contaminant concentration was less than the screening concentration, the health risk assessment process could be terminated; otherwise, the health risk assessment needed to continue. In addition, since the toxicity of some pollutants was age-sensitive, this specification introduced age-sensitive factors to calculate the excess carcinogenic risk of air pollutants accurately. The calculation methods of exposure concentration of carcinogenic and non-carcinogenic air pollutants were listed in detail in the exposure assessment. Excess carcinogenic risk assessment, non-carcinogenic risk assessment, and uncertainty analysis were listed in the health risk assessment.

RECOMMENDATIONS

The technical specifications (WS/T 666-2019) came into effect on January 1, 2020 and were directly applicable to assessing the health risk of air pollutants inhaled into the human body at the local, regional, and national levels. These technical specifications have provided general rules for assessing the health risk of air pollution, including the basic principles of the assessment, the assessment process, the formulation of plans, selection methods, feedback procedures and next steps, implementation of the assessments, sources of uncertainty in the assessments, risk assessment reports, and application of results, etc. The workflow, assessment methods, and requirements of two kinds of assessment methods based on population characteristic data and pollutant toxicity were specified. Appendices were provided, including a case of air pollution population health risk assessment, a report template, etc. These technical specifications can guide evaluators to choose appropriate assessment methods, tools, and data resources that meet the requirements, carry out the health risk assessment, and reasonably interpret the assessment results.

Population-based Health Risk Assessments

Population-based health risk assessments provided assessment methods by using populationepidemiological data. Acute health risk assessment methods can be used to assess the health risks of heavy pollution and phased or temporary air pollution prevention and control. The exposure-response coefficient can be the results of time series and casecrossover studies. The results of chronic health risk assessments are preferred in the formulation of standard limits of air pollutants and long-term targets for the prevention and control of air pollution. The coefficient can be obtained from cohort studies or cross-sectional studies. In addition, coefficients should give preference to results of local or regional similarities in climate, geography, exposure levels, economy, and customs. Exposure assessments should consider the range of concentration of air pollutants people are exposed to and focus on those at high health risks. In risk characterization analysis, the selection of reference concentration should consider not only the purpose of risk assessment, but also the level of economic development and technical feasibility. This method takes into account the exposure of the population and the impact of pollutants on human health and is closer to the real risk of air pollution on human health. However, it is difficult to obtain and accurately evaluate the population data.

Toxicity-based Health Risk Assessments

Toxicity-based carcinogenic and non-carcinogenic health risk assessments can be conducted when contaminant concentration and toxicity data are available. Age-sensitive factors were introduced into carcinogenic risk assessments, and 1×10^{-6} was recommended as the acceptable carcinogenic risk. For non-carcinogenic risks, acute, sub-chronic, and chronic exposures were considered. Hazard quotient one was considered as the acceptable risk of non-carcinogenic air pollutants. In actual scenarios, people are often exposed to multiple air pollutants at the same time, or to one or more air pollutants intermittently. Therefore, cumulative exposure needs to be calculated in exposure assessments. The required parameters in this method are easy to obtain, but since the results based on toxicological data involve extrapolation of experimental results, the uncertainty of population health risk assessment results is greater.

COMMENT

These technical specifications (WS/T 666–2019) are the first on environmental health risk assessment issued by China's health authorities, which promotes the establishment of a health risk assessment system and facilitates the implementation of the "integrate health into all policies" strategy. Since the release of the specifications, China CDC has conducted technical specification training for provincial and municipal CDC staff who carry out air pollution and health impact monitoring, standardized air pollution health risk assessment methods, and promoted the extensive development of health risk assessment work. The extensive application of monitoring data in local areas provides a scientific basis for the formulation of air pollution control policies and environmental health management. In addition, it can help all readers better understand the risk assessment results and facilitate improved communication of risks.

Conflicts of interest: No conflicts of interest.

Funding: The National Health and Family Planning Commission of the People's Republic of China (201402022 and 201502003).

doi: 10.46234/ccdcw2021.175

[#] Corresponding author: Dongqun Xu, xudq@chinacdc.cn.

Submitted: June 07, 2021; Accepted: August 10, 2021

REFERENCES

- GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet 2020;396 (10258):1223 – 49. http://dx.doi.org/10.1016/S0140-6736(20)30752-2.
- Disease Prevention and Control Bureau, National Health Commission, PRC. Work plan for air pollution (Smog) health impact monitoring work program, in 2013. http://www.nhc.gov.cn/jkj/s5898bm/201310/ 02c483b454264c4aa0e99d580fc91c71.shtml. [2013–10–15]. (In Chinese).
- 3. National Public Service Platform for Standards Information. Industry standard information platform. http://hbba.sacinfo.org.cn/stdList?key= health risk & ministry=wsjkwyh. [2021–6–9]. (In Chinese).
- National Health Commission of the People's Republic of China. Technical specifications for health risk assessment of ambient air pollution (WS/T 666–2019). http://www.nhc.gov.cn/fzs/s7848/ 201907/3baff64579a54d5585923a272dfcbcf2.shtml. (In Chinese).
- World Health Organization. Health risk assessment of air pollution general principles. Copenhagen: WHO Regional Office for Europe; 2016. https://www.euro.who.int/__data/assets/pdf_file/0006/298482/ Health-risk-assessment-air-pollution-General-principles-en.pdf.
- World Health Organization. WHO Expert Meeting: methods and tools for assessing the health risks of air pollution at local, national and international level. Bonn, Germany: WHO Regional Office for Europe; 2014. https://extranet.who.int/iris/restricted/handle/10665/143712.
- 7. US Environmental Protection Agency. Guidelines for exposure assessment. Washington, DC: US Environmental Protection Agency, Risk Assessment Forum; 1992. Report No.: EPA/600/Z-92/001. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=15263.

708

¹ China CDC Key Laboratory of Environment and Population Health, National Institute of Environmental Health, Chinese Center for Disease Control and Prevention, Beijing, China.

- US Environmental Protection Agency. Guidelines for the health risk assessment of chemical mixtures. Washington, DC: US Environmental Protection Agency, Risk Assessment Forum; 1986. Report No.: EPA/630/R-98/002. https://www.epa.gov/risk/guidelines-health-riskassessment-chemical-mixtures.
- US Environmental Protection Agency. Guidelines for carcinogen risk assessment. Washington, DC: US Environmental Protection Agency, Risk Assessment Forum; 2005. Report No.: EPA/630/P-03/001F. https://www.epa.gov/risk/guidelines-carcinogen-risk-assessment.
- 10. US Environmental Protection Agency. A review of the reference dose

and reference concentration processes. Washington, DC: US Environmental Protection Agency, Risk Assessment Forum; 2002. Report No.: EPA/630/P-02/002F. https://www.epa.gov/sites/default/ files/2014-12/documents/rfd-final.pdf.

11. US Environmental Protection Agency. Risk assessment guidance for superfund (RAGS), volume I: human health evaluation manual (Part F, supplemental guidance for inhalation risk assessment). Washington, DC: US Environmental Protection Agency; 2009. Report No.: EPA 540-R-070-002. http://www.eugris.info/displayresource.aspx?r=6882.

Copyright © 2021 by Chinese Center for Disease Control and Prevention

All Rights Reserved. No part of the publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise without the prior permission of CCDC Weekly. Authors are required to grant CCDC Weekly an exclusive license to publish.

All material in CCDC Weekly Series is in the public domain and may be used and reprinted without permission; citation to source, however, is appreciated.

References to non-China-CDC sites on the Internet are provided as a service to *CCDC Weekly* readers and do not constitute or imply endorsement of these organizations or their programs by China CDC or National Health Commission of the People's Republic of China. China CDC is not responsible for the content of non-China-CDC sites.

The inauguration of *China CDC Weekly* is in part supported by Project for Enhancing International Impact of China STM Journals Category D (PIIJ2-D-04-(2018)) of China Association for Science and Technology (CAST).



Responsible Authority

National Health Commission of the People's Republic of China

Sponsor

Chinese Center for Disease Control and Prevention

Editing and Publishing

China CDC Weekly Editorial Office No.155 Changbai Road, Changping District, Beijing, China Tel: 86-10-63150501, 63150701 Email: weekly@chinacdc.cn

CSSN ISSN 2096-7071 CN 10-1629/R1