Preplanned Studies

Development of the National Air Quality Health Index — China, 2013–2018

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Summary

What is already known about this topic?

While the establishment of an air quality health index (AQHI) in some countries yielded positive outcomes in communicating health risks of air pollution, China lagged behind in developing its own AQHI. Several research studies of AQHI were conducted in China, but this scientific research has not yet been applied to standards.

What is added by this report?

This report introduced the method of calculation of Chinese AQHI to be launched in pilot cities. The index in this report was established on the basis of fully drawing on international experience and considering Chinese characteristics.

What are the implications for public health practice?

The purpose of this report is to guide unified application of the AQHI throughout China and translate scientific evidence into public services to promote public health. Based on the AQHI construction method in this report, an AQHI real-time computing platform and data transfer interface will be developed. The release of AQHI aims to communicate health risk of air pollution and provide scientific health protective guidance to the general public, accordingly to protect people's health.

Air pollution was among the leading ten health risk factors in 1990 and remained an important factor as of 2016 (*1*). Since air pollution control is a long-term challenge, China is likely to encounter more air pollution related health issues going forward. In environmental health risk communication aimed at protecting public health, an air quality index will play a significant role.

The United States Environmental Protection Agency (EPA) started using the Pollutant Standards Index (PSI) to report the daily air quality index in 1976. Since 1999, the EPA replaced the PSI with the Air Quality Index (AQI) (*2*). This standard is now commonly adopted worldwide. In communicating air pollution health risks, the AQI avoids confusion caused by listing various pollutant concentrations. However, AQI is not intended to indicate health risks of air quality, so the usefulness of the AQI is inherently limited. Briefly, the AQI calculates air quality based on limits for different pollutants. Air quality standards are based on a variety of factors, including technical and economic accessibility as air quality management objectives. Nevertheless, AQI could not reflect the non-threshold concentration-response relationship between air pollutant(s) and health consequence(s). Moreover, AQI does not reflect the combined health effects of many air pollutants.

To better communicate health risks of air pollution to the general public, Canada considered some health risk parameters and introduced a new index system called the Air Quality Health Index (AQHI) (*3*). Based on the Canadian approach, Hong Kong, China developed an AQHI reporting system in 2013 (*4*). More recently, some studies in China discussed the construction of an AQHI from scientific perspectives for a single city, multiple cities, and nationwide. These studies suggested that the AQHI could better reflect the health risks of air pollution in China. Nevertheless, these studies covered few areas or were insufficiently validated because of data scarcity and most have not released to the public.

In order to develop a Chinese AQHI reporting system, the National Health Commission (NHC) and China CDC commissioned the National Institute of Environmental Health to study the development of a Chinese AQHI. This report introduced the construction method of Chinese AQHI to guide unified application of AQHI throughout China.

Chinese AQHI was constructed by referencing and improving on the approach of Stieb et al. (*3*). During the construction of AQHI, three key points were the included pollutants, preferred health outcomes, and chosen scaling parameter.

The air pollutants of AQHI in this report include $PM_{2.5}$, O_3, NO_2, and SO_2 (the rationale is discussed in the Supplementary Material). The descriptive analysis of national county-level pollutants was shown in Table 1.

Mortality was chosen as the health outcome due to its severity and because mortality data are more objective and have better quality in China. The burden of disease attributable to air pollution in the Global Burden of Disease study and the WHO air quality guidelines for particulate matter were also calculated based on mortality data (*5*). The chosen outcome was non-accidental mortality to reflect the overall health impact.

The AQHIs were scaled by dividing by the 99th percentile for the time period, instead of dividing by the maximum value like other studies. Pollution levels can vary widely from region to region in China, and some regions had incidents of heavy pollution events. If divided by the maximum value, the indices in many areas would present low risk, which would mislead the users of this index.

Based on the above consideration, the Chinese AQHI was constructed. Hourly concentrations of $PM_{2.5}$, O_3, SO_2, and NO_2 were collected from 2013 to 2018 in 769 counties of China (Figure 1). The regression coefficient β was derived from the regression models relating air pollutants ($PM_{2.5}$, O_3, SO_2, and NO_2) (*6*–*9*) to mortality in China (Table 2).

Daily excess percentage risks of mortality relative to zero concentration, for non-threshold exposure-response relationship between air pollutant(s) and health consequence(s), of exposure to each pollutant in each day from 2013 to 2018 were calculated (Formula 1). Then the sum of daily excess percentage risks of mortality of the 4 pollutants at day t were calculated, then the 99th percentile at each study site was calculated (Formula 2). AQHI was separated into 11 levels of 1–10 and 10+ at each county at any day t in the past and the future (Formula 3).

$$ER_{ijt} = 100 \times \left[exp\left(\beta_i \times x_{ijt}\right) - 1 \right] \qquad (1)$$

where ER_{ijt} represents the daily excess percentage risk of mortality associated with the pollutant i in j county at t day, β_i was the regression coefficient of pollutant i from previous studies, x_{ijt} was the mean concentration of pollutant i in j county at t day.

$$ER_{P99} = P99_{\substack{j=1\cdots n \\ t=1\cdots m}} \left[\Sigma_{i=1\cdots q}\left(ER_{ijt} \right) \right] \qquad (2)$$

where ER_{P99} represents the 99th percentile of daily sum of excess percentage risk of mortality associated with $PM_{2.5}$, O_3, NO_2, and SO_2 in each county of all 769 counties at each day from 2013 to 2018. The result of ER_{P99} was 20.04.

$$AQHI_{jt} = \left(ER_{jt} \times 10 \right) / ER_{P99} \qquad (3)$$

where ER_{jt} represents the daily sum of excess percentage risk of mortality associated with the $PM_{2.5}$, O_3, NO_2, and SO_2 in j county at t day.

Table 1 summarized the descriptive analysis of county-level pollutants and AQHI during 2013–2018 in China. The averaged levels of AQHI were 4. The frequency distribution of AQHI in 36 cities (all municipalities directly under the central government, cities specifically designated in the state plan, and provincial-level capitals of China) from 2013–2018 was shown in Supplementary Table S1 available in http://weekly.chinacdc.cn/.

For the convenience of public communication, AQHI values (1–10+) were grouped into 4 levels: low health risk (1–3), moderate health risk (4–6), high health risk (7–10), and very high health risk (10+). According to different health risk levels (including low, moderate, high, and very high health risk levels), health protective messages will be provided to the general population, patients with cardiopulmonary disease, and sensitive populations (including the elderly, pregnant woman, and children), respectively.

DISCUSSION

This report introduced the method of calculating the Chinese AQHI. This AQHI was established based on

TABLE 1. Descriptive analysis of county-level pollutants and air quality health index (AQHI) of China, 2013–2018.

Variable	Effective days	Mean ± SD	Min	P_{25}	Median	P_{75}	Max
Pollution							
$PM_{2.5}$ (μg/m^3)	1,332,272	51.1 ± 43.3	3.0	23.9	39.0	63.7	806.6
NO_2 (μg/m^3)	1,333,267	34.3 ± 20.7	1.0	19.1	29.9	44.9	471.1
SO_2 (μg/m^3)	1,335,313	22.9 ± 26.7	2.9	8.7	14.7	26.4	715.7
O_3 (μg/m^3)	1,326,722	59.6 ± 31.8	2.1	35.7	55.4	79.0	625.3
AQHI	1,307,118	4.0 ± 1.7	1	3	4	5	10+

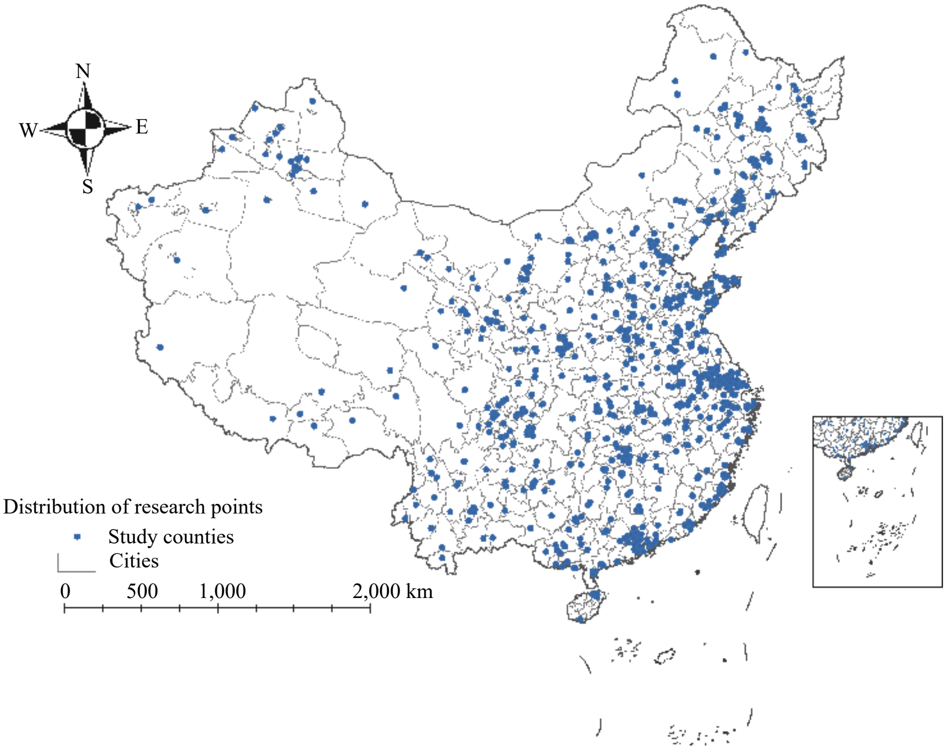

FIGURE 1. Distribution of 769 counties of the National air quality health index study in China from 2013 to 2018.

TABLE 2. Exposure-response relationships of air pollution and non-accidental mortality.

Pollutant	β value
$PM_{2.5}$	0.00022
O_3	0.00024
NO_2	0.00090
SO_2	0.00059

daily $PM_{2.5}$, O_3, NO_2, and SO_2 concentration of 769 counties and the exposure-response relationship between air pollution and mortality. The AQHI should be an effective tool to reflect and communicate the health risk of air pollution with the public in China.

Compared with research from Du et al. (*10*), this report has several differences: different research regions, different included pollutants, and different index of standardization. This report included almost all counties with national air pollution monitoring stations in China, which provided higher regional resolution and better data. Considering the concentration of SO_2 is still relatively high in some regions of China, our report also included this pollutant to be a better indicator of health risks.

While several factors were considered based on the current data, this method has several limitations. First, a uniform set of parameters and formulas across the nation could cause bias in some regions. Using regional exposure-response relationships and combining certain pollutants could provide a more accurate indication of the health risks of short-term exposure to air pollution. Nonetheless, in public communication, getting the index understood and avoiding conflicting results in different regions are more important than finding the best index. Hence, an AQHI was constructed with the idea of simplifying the information. Second, the β value used in this study was extracted from ecological studies which might contain inherent biases. In future studies, the index should be updated with better exposure-response relationships.

Additional validation of the AQHI is required. More relevant health data will be collected to further verify, evaluate, and optimize the index. Furthermore, more attention should be focused on the evaluation of the effectiveness of the AQHI application. To evaluate the effectiveness of the AQHI implementation, relevant data of differences-in-differences estimates before and after the AQHI application in county with and without published AQHI data will be collected in the next few years. The index will be adjusted and optimized based on the validation results

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Supplementary Material

The rationale of using $PM_{2.5}$, O_3, NO_2, and SO_2 to construct the air quality health index (AQHI):

Similar to previous studies in Guangzhou Province (*1*) and New York City (*2*), the air pollutants in the AQHI included $PM_{2.5}$, O_3, NO_2, and SO_2. In Hong Kong, China, the developed AQHI were based on the health effects of PM_{10}, O_3, SO_2 (*3*), and NO_2. While in Canada, the established AQHI were based on the health effects of $PM_{2.5}$, O_3, and NO_2 (*4*). The inclusion of O_3 and NO_2 is not controversial. Considering the collinearity of $PM_{2.5}$ and PM_{10}, and the health hazard differences between them, $PM_{2.5}$ was chosen in our calculations. SO_2 was included by considering the pollution types in different regions of China. Several studies revealed that SO_2 was strongly associated with total mortality risk (*5*–*6*). SO_2 pollution mainly comes from the combustion of sulfur-containing fossil fuels (*7*). Notably, China is a country with massive coal production and consumption (*8*). According to the Bulletin of China’s Ecological Environment 2018, the yearly average concentration of SO_2 in the Fen-Wei Plains was 24 μg/m^3 in 2018 (*9*). According to our data in 2013–2018 (Supplementary Table S1), more than 25% of daily average concentration of county was higher than 26 μg/m^3. Therefore, the health risk of SO_2 pollution in China still needs to be considered.

SUPPLEMENTARY TABLE S1. Frequency distribution of air quality health index (AQHI) in 36 cities* of China, 2013–2018.

City	Level	Frequency	Distribution
Xiamen	[1,3]	1,381	68.64%
	(3,6]	609	30.27%
	(6,10]	22	1.09%
	(10,10+]	0	0%
Shenzhen	(1,3]	1,345	66.68%
	(3,6]	657	32.57%
	(6,10]	15	0.74%
	(10,10+]	0	0%
Dalian	(1,3]	959	47.62%
	(3,6]	968	48.06%
	(6,10]	84	4.17%
	(10,10+]	3	0.15%
Qingdao	(1,3]	705	34.88%
	(3,6]	1,183	58.54%
	(6,10]	121	5.59%
	(10,10+]	12	0.59%
Ningbo	(1,3]	748	37.12%
	(3,6]	1,172	58.16%
	(6,10]	92	4.57%
	(10,10+]	3	0.15%
Beijing	(1,3]	628	31.99%
	(3,6]	1,076	54.81%
	(6,10]	227	11.56%
	(10,10+]	32	1.63%
Shanghai	(1,3]	539	26.74%
	(3,6]	1,321	65.53%
	(6,10]	148	7.34%
	(10,10+]	8	0.40%

Continued

City	Level	Frequency	Distribution
Tianjin	(1,3]	398	19.77%
	(3,6]	1,234	61.30%
	(6,10]	317	15.75%
	(10,10+]	64	3.18%
Chongqing	(1,3]	704	34.90%
	(3,6]	1,273	63.11%
	(6,10]	40	1.98%
	(10,10+]	0	0%
Hefei	(1,3]	720	35.80%
	(3,6]	1,206	59.97%
	(6,10]	85	4.23%
	(10,10+]	0	0%
Fuzhou	(1,3]	1,502	74.58%
	(3,6]	508	25.22%
	(6,10]	4	0.20%
	(10,10+]	0	0%
Lanzhou	(1,3]	484	24.02%
	(3,6]	1,377	68.34%
	(6,10]	153	7.59%
	(10,10+]	1	0.05%
Guangzhou	(1,3]	798	39.62%
	(3,6]	1,086	53.92%
	(6,10]	125	6.21%
	(10,10+]	5	0.25%
Guilin	(1,3]	1,121	66.33%
	(3,6]	542	32.07%
	(6,10]	25	1.48%
	(10,10+]	2	0.12%
Guiyang	(1,3]	1375	68.24%
	(3,6]	603	29.93%
	(6,10]	37	1.84%
	(10,10+]	0	0%
Haikou	(1,3]	1,948	96.72%
	(3,6]	66	3.28%
	(6,10]	0	0%
	(10,10+]	0	0%
Shijiazhuang	(1,3]	250	12.39%
	(3,6]	1,113	55.18%
	(6,10]	463	22.95%
	(10,10+]	191	9.47%
Zhengzhou	(1,3]	1,345	66.68%
	(3,6]	657	32.57%
	(6,10]	15	0.74%
	(10,10+]	0	0%

Continued

City	Level	Frequency	Distribution
Harbin	(1,3]	789	39.12%
	(3,6]	882	43.73%
	(6,10]	264	13.09%
	(10,10+]	82	4.07%
Wuhan	(1,3]	493	24.52%
	(3,6]	1,198	59.57%
	(6,10]	293	14.57%
	(10,10+]	27	1.34%
Changsha	(1,3]	818	40.62%
	(3,6]	1,050	52.14%
	(6,10]	146	7.25%
	(10,10+]	0	0%
Changchun	(1,3]	660	32.77%
	(3,6]	1,126	55.91%
	(6,10]	212	10.53%
	(10,10+]	16	0.79%
Nanjing	(1,3]	438	21.73%
	(3,6]	1,339	66.42%
	(6,10]	228	11.31%
	(10,10+]	11	0.55%
Nanchang	(1,3]	973	48.31%
	(3,6]	963	47.82%
	(6,10]	75	3.72%
	(10,10+]	3	0.15%
Shenyang	(1,3]	402	20.00%
	(3,6]	1,181	58.76%
	(6,10]	324	16.12%
	(10,10+]	103	5.12%
Hohhot	(1,3]	538	26.74%
	(3,6]	1,229	61.08%
	(6,10]	237	11.78%
	(10,10+]	8	0.40%
Yinchuan	(1,3]	530	26.38%
	(3,6]	1,108	55.15%
	(6,10]	315	15.68%
	(10,10+]	56	2.79%
Xining	(1,3]	553	27.43%
	(3,6]	1,404	69.64%
	(6,10]	59	2.93%
	(10,10+]	0	0%
Jinan	(1,3]	133	6.58%
	(3,6]	1,385	68.50%
	(6,10]	421	20.82%
	(10,10+]	83	4.10%

Continued

City	Level	Frequency	Distribution
Taiyuan	(1,3]	320	15.90%
	(3,6]	1,198	59.54%
	(6,10]	399	19.83%
	(10,10+]	95	4.72%
Xi'an	(1,3]	365	18.13%
	(3,6]	1,344	66.77%
	(6,10]	264	13.11%
	(10,10+]	40	1.99%
Chengdu	(1,3]	387	19.22%
	(3,6]	1,422	70.61%
	(6,10]	198	9.83%
	(10,10+]	7	0.35%
Lhasa	(1,3]	1,792	88.98%
	(3,6]	222	11.02%
	(6,10]	0	0%
	(10,10+]	0	0%
Urumchi	(1,3]	530	26.36%
	(3,6]	1,161	57.73%
	(6,10]	292	14.52%
	(10,10+]	28	1.39%
Kunming	(1,3]	1,255	62.31%
	(3,6]	755	37.49%
	(6,10]	4	0.20%
	(10,10+]	0	0%
Hangzhou	(1,3]	709	35.19%
	(3,6]	1,228	60.94%
	(6,10]	76	3.77%
	(10,10+]	2	0.10%

Note: 36 cities reffer to all municipalities directly under the central government, cities specifically designated in the state plan, and provincial-level capitals.

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