

Preplanned Studies

Baseline Investigation on Residential PM_{2.5} Pollution of General Living Scenarios — 12 Cities, China, 2018

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Summary

What is already known about this topic?

Residential air pollution can cause a large disease burden, and residential air quality is directly influenced by residential fine particulate matter (PM_{2.5}). Residential PM_{2.5} pollution is of critical concern in China given that the characteristics and influencing factors of residential PM_{2.5} in China are not clear.

What is added by this report?

This study focused on residential PM_{2.5} concentration of 12 cities with the on-site investigation in 2018, and provided the latest characteristics and potential influencing factors of residential PM_{2.5} under general living scenarios in China.

What are the implications for public health practice?

This study suggested that the control of residential PM_{2.5} pollution should be reinforced with revised indoor air quality standards under obvious spatial diversity.

Short-term and long-term exposure to outdoor airborne fine particulate matter (particles with aerodynamic diameter $\leq 2.5 \mu\text{m}$; PM_{2.5}) can increase the morbidity and mortality of cardiovascular and respiratory diseases (1). Considering time-activity patterns, people spent 85%–90% of their daily time in households (2), and for indoor PM_{2.5} pollution, some studies were reported from many countries with a focus on special conditions such as residential ventilation, biofuel combustion, environmental tobacco smoke, etc (3–4). With rapid urbanization, residential PM_{2.5} pollution still remains to be studied in many cities of China, especially under daily general living circumstances.

To explore the representative levels, characteristics, and influencing factors of residential PM_{2.5} pollution in China, the National Institute of Environmental Health (NIEH) of China CDC initiated a multicenter investigation for indoor air pollution in 2018. The

study selected cities and resident families based on two-step random sampling. Twelve representative cities were selected considering various factors such as climatic and geographical locations. These cities were mainly from the Northeast (Harbin and Panjin), Northwest (Lanzhou and Xi'an), Southwest (Mianyang), North (Shijiazhuang), East (Wuxi, Ningbo and Qingdao), Central (Luoyang), and South (Nanning and Shenzhen) of China. The selected cities within the zone of temperate climate were Harbin, Panjin, Qingdao, Shijiazhuang, Lanzhou, Luoyang, and Xi'an, and the selected cities within the zone of subtropical climate included the other five cities. The sampling dates were in the cold season (December) and the warm season (June) in 2018. Samples from families of Xi'an and Mianyang were collected only in the cold season because of unexpected interruptions to the field investigation.

Resident families in each city were randomly selected from one district downwind of the city center and another district located upwind. At least 25 families in each district were identified as confirmed target households with the following inclusion criteria: 1) families lived in the house for more than 3 years without plans to move away in the next 3 years; 2) families included at least one infant; and 3) families were willing to participate in this investigation. Families including individuals engaged in occupations with high health risks caused by environmental pollution and with any individuals smoking regularly were excluded.

In order to collect representative data of residential air quality, samples from bedrooms and living rooms of each family were collected by local CDCs. To collect the data of residential pollution with many parameters such as PM_{2.5} related to the unified general living scenario of each household, the sampling condition of each family was regulated with the following guidelines: 1) the doors and windows were pre-closed for 12 hours for indoor sampling; 2) air conditioners, fans, and other equipment that may interfere with

airflow were all turned off during the sampling period; 3) the period between 9 AM to 10 AM was chosen as the preferred sampling time to avoid traffic peaks and indoor cooking; 4) behaviors like indoor smoking were prohibited and temporary visiting guests were avoided for sampling in all families under the general living circumstances; 5) the height of the measuring point was 1 to 1.5 meters above the ground; and 6) the measuring point was not less than 0.5 meters from the wall. Indoor air quality indicators in this study included temperature, humidity, PM_{2.5}, PM₁₀ (particles with aerodynamic diameter $\leq 10 \mu\text{m}$; PM₁₀), etc. PM_{2.5} and PM₁₀ were monitored by calibrated light-scattering dust meters. The average value of 10 monitoring values recorded on a 5 minute interval was consistently taken as the final representative concentration for a site in living rooms and bedrooms. Approximately 3% of the total rooms were monitored repetitively as the parallel sites, and the sampling method had acceptable repeatability. The family members were interviewed about the lifestyles and living conditions of households with questionnaires. Informed consent forms were signed before the investigation. The sample size of target families was calculated based on a cross-sectional study design. Finally, after accounting for data censoring and the lack of coordination of the families, a total of 642 families were identified to evaluate residential air pollution in 12 major cities in China.

In 2018, the population in all selected cities was exposed to a residential PM_{2.5} average concentration of 79.34 $\mu\text{g}/\text{m}^3$, and the PM_{2.5} concentration

distribution in each city was also shown (Table 1). A significant difference was found in PM_{2.5} concentrations among 12 cities ($F=72.13$, $p<0.001$). The concentration of residential PM_{2.5} in two seasons was significantly different in 7 representative cities including Harbin, Panjin, Qingdao, Shijiazhuang, Lanzhou, Luoyang, and Wuxi ($p<0.05$) (Figure 1).

Residential PM_{2.5} concentration in this study was not normally distributed, so we estimated the odds ratio and corresponding 95% confidence interval (95% CI) for each potential risk factor by using the generalized linear model (GLM) with Poisson connection function (Table 2). After adjusting for the influence of PM₁₀, the concentrations of residential PM_{2.5} in warm climate zones were found to be likely higher than those in the cold climate zone ($\text{OR}_2=1.4454$, 95% CI: 1.3973–1.4951). Statistically significant associations were found with residential PM_{2.5} and physical indicators including temperature ($\text{OR}_2=0.9436$, 95% CI: 0.9406–0.9465) and humidity ($\text{OR}_2=0.9906$, 95% CI: 0.9894–0.9918). For the residential environment, households more than 1 kilometer away from the road had a lower residential PM_{2.5} concentration than those less than 1 kilometer ($\text{OR}_2=0.7511$, 95% CI: 0.7103–0.7937).

Architectural characteristics showed potential influences on residential PM_{2.5}. As to the layers of window glass, the PM_{2.5} concentrations in families with more than two layers were higher than those of less than two layers ($\text{OR}_2=1.2841$, 95% CI: 1.1694–1.4066). In addition, the PM_{2.5} concentrations in households between the 5th and

TABLE 1. Description of residential PM_{2.5} of 12 cities in China, 2018 ($\mu\text{g}/\text{m}^3$).

Cities	Mean	SD	Min	P ₂₅	P ₅₀	P ₇₅	Max
Harbin	38.03	26.37	0.00	21.75	31.50	47.00	193.00
Panjin	83.10	50.33	9.00	54.25	73.45	96.48	541.00
Qingdao	49.24	48.68	9.00	20.00	35.00	54.50	272.00
Shijiazhuang	66.60	47.21	4.00	33.00	60.50	90.00	295.00
Lanzhou	174.30	150.41	0.00	89.25	144.50	232.75	968.00
Luoyang	83.65	65.72	8.00	43.25	62.00	109.00	380.00
Xi'an	101.88	102.88	14.00	46.75	76.50	120.25	690.00
Wuxi	68.96	66.72	2.00	26.50	45.00	85.50	401.00
Mianyang	220.38	156.67	60.00	90.00	182.50	349.50	531.00
Ningbo	33.09	21.39	5.00	16.00	27.90	50.65	102.83
Nanning	59.60	13.36	24.00	54.50	65.00	70.00	74.00
Shenzhen	43.82	23.51	11.00	29.25	41.00	49.00	137.00

Note: To correct the extreme value of PM_{2.5} in Lanzhou, we used the 95% quantile of the same city in the same season to take place of it. Abbreviations: SD=standard deviation, Min=minimum, P₂₅=25th percentile, P₅₀=median, P₇₅=75th percentile, Max=maximum.

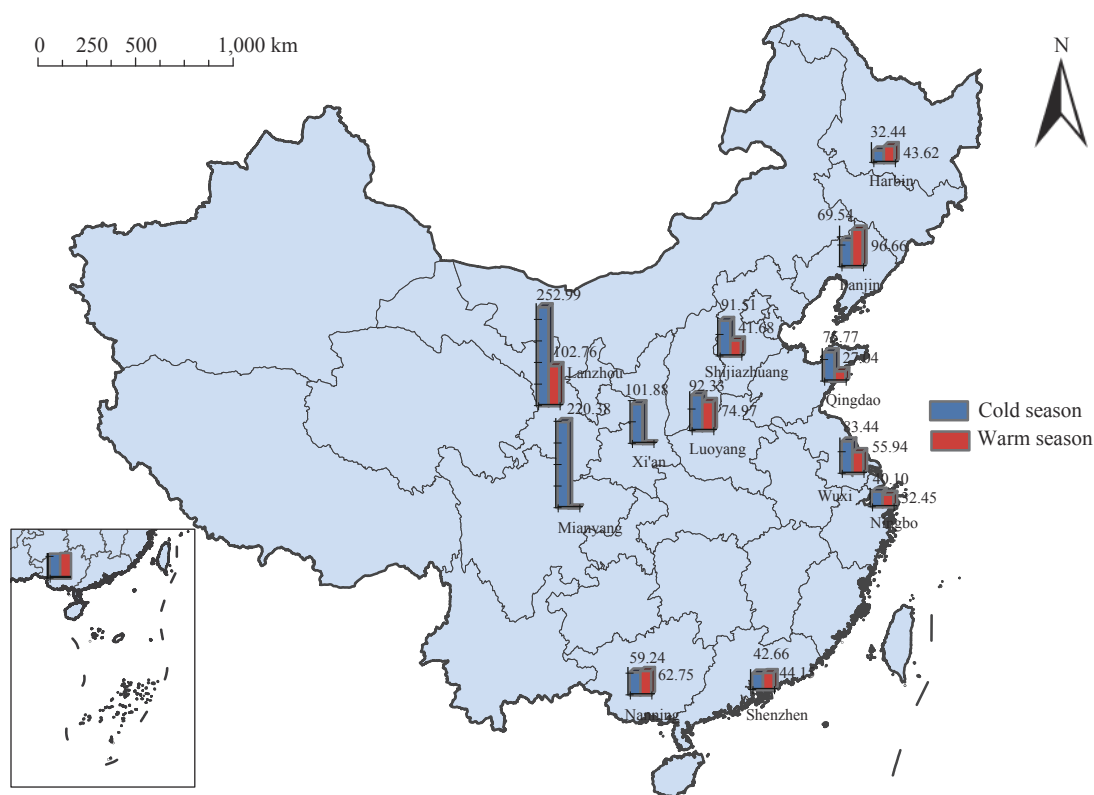


FIGURE 1. Spatial and seasonal distribution of residential $PM_{2.5}$ of 12 cities in China, 2018 ($\mu\text{g}/\text{m}^3$).

10th floors ($OR_2=1.1102$, 95% CI: 1.0788–1.1425) and above 10th floor ($OR_2=1.1616$, 95% CI: 1.1276–1.1965) were higher than those in households below the 5th floor. Compared with bungalows, the residential $PM_{2.5}$ concentrations were higher in buildings ($OR_2=1.3860$, 95% CI: 1.3028–1.4760).

Some family-related information and lifestyle habits may also influence residential $PM_{2.5}$. As for the influence of family economic status, compared with families with an annual total income of fewer than 100,000 RMB (roughly 14,300 USD), households with an annual income of 100,000 to 200,000 RMB ($OR_2=0.8209$, 95% CI: 0.8004–0.8419) and an income of more than 200,000 RMB ($OR_2=0.8074$, 95% CI: 0.7778–0.8379) had lower residential $PM_{2.5}$ concentrations. The study also found that the average living area of family members showed a positive correlation with residential $PM_{2.5}$ concentration ($OR_2=1.0020$, 95% CI: 1.0008–1.0032). As for lifestyle habits, the $PM_{2.5}$ concentrations of households that never use air purifiers were significantly higher than those families using air purifiers ($OR_2=1.0856$, 95% CI: 1.0551–1.1170). The frequency of using the range hood in the kitchen was also correlated with residential $PM_{2.5}$. The $PM_{2.5}$

concentrations in households using range hoods frequently ($OR_2=0.8864$, 95% CI: 0.8207–0.9588) and occasionally ($OR_2=0.5241$, 95% CI: 0.4366–0.6253) were lower than those that never used the range hoods. Moreover, households without carpets showed lower $PM_{2.5}$ concentrations than those with carpets ($OR_2=0.8027$, 95% CI: 0.7699–0.8372), and households that never grow plants had a higher $PM_{2.5}$ concentration than those grow plants ($OR_2=1.0284$, 95% CI: 1.0020–1.0555).

DISCUSSION

This study was one of few studies that uses extensive multi-center data obtained through face-to-face surveys in China. Variability in residential $PM_{2.5}$ concentrations in 12 cities was possibly related to a combination of differences in the sources of pollution (road dust, automobile exhaust, and coal combustion sources) (5), meteorological factors (wind speed, atmospheric stability), and family living habits. Seasonal variations of $PM_{2.5}$ in 7 representative cities may be caused partially by outdoor temperature and humidity (3). Moreover, we found significant correlations between residential $PM_{2.5}$ and physical

TABLE 2. Some potential influencing factors and the concentrations of residential PM_{2.5} of 12 cities in China, 2018.

Variables	Categories	OR ₁ (95% CI)	<i>p</i> ₁	OR ₂ (95% CI)	<i>p</i> ₂
PM ₁₀ (μg/m ³)				1.0055 (1.0054, 1.0056)	<0.001
Temperature (°C)		0.9286 (0.9258, 0.9315)	<0.001	0.9436 (0.9406, 0.9465)	<0.001
Humidity (%)		0.9938 (0.9926, 0.9949)	<0.001	0.9906 (0.9894, 0.9918)	<0.001
Climate zones (vs. Cold)	Warm	0.9840 (0.9535, 1.0154)	0.315	1.4454 (1.3973, 1.4951)	<0.001
Distance from road (vs. <1 km)	>1 km	0.7739 (0.7328, 0.8167)	<0.001	0.7511 (0.7103, 0.7937)	<0.001
Window glass types (vs. ≤2 layers)	>2 layers	0.8546 (0.7792, 0.9349)	<0.001	1.2841 (1.1694, 1.4066)	<0.001
Living floor (vs. ≤5)	5–10	1.1160 (1.0846, 1.1481)	<0.001	1.1102 (1.0788, 1.1425)	<0.001
	≥10	1.1742 (1.1398, 1.2094)	<0.001	1.1616 (1.1276, 1.1965)	<0.001
Construction house types (vs. Bungalow)	Building	1.1953 (1.1245, 1.2719)	<0.001	1.3860 (1.3028, 1.4760)	<0.001
	Villa	0.6682 (0.5787, 0.7685)	<0.001	0.8942 (0.7737, 1.0292)	0.124
Renovate in the past 5 years (vs. Yes)	No	1.0519 (1.0259, 1.0787)	<0.001	0.9912 (0.9663, 1.0168)	0.496
Income (yearly) (vs. <100,000 RMB)	100,000–200,000 RMB	0.9030 (0.8803, 0.9263)	<0.001	0.8209 (0.8004, 0.8419)	<0.001
	≥200,000 RMB	0.7842 (0.7555, 0.8139)	<0.001	0.8074 (0.7778, 0.8379)	<0.001
Average living area (m ²)		0.9949 (0.9938, 0.9961)	<0.001	1.0020 (1.0008, 1.0032)	0.001
House cleaning (vs. More than once a month)	Less than once a month	2.8896 (2.5724, 3.2339)	<0.001	0.9506 (0.8447, 1.0660)	0.393
Grow plants (vs. Yes)	No	1.1078 (1.0798, 1.1364)	<0.001	1.0284 (1.0020, 1.0555)	0.034
Carpet (vs. Yes)	No	0.7953 (0.7630, 0.8294)	<0.001	0.8027 (0.7699, 0.8372)	<0.001
Burn incense (vs. Yes)	No	1.0935 (1.0538, 1.1350)	<0.001	0.9965 (0.9599, 1.0347)	0.853
Air purifier (vs. Yes)	No	1.0480 (1.0188, 1.0781)	0.001	1.0856 (1.0551, 1.1170)	<0.001
Range hook (vs. Never)	Occasionally	0.6214 (0.5178, 0.7411)	<0.001	0.5241 (0.4366, 0.6253)	<0.001
	Frequently	1.0849 (1.0048, 1.1731)	0.039	0.8864 (0.8207, 0.9588)	0.002

Note: The variables after vs. represent the reference variables in statistical analysis. The value of OR₁ indicates that while keeping other predictor variables unchanged, the logarithm of residential PM_{2.5} concentration was OR₁ times of the individual reference variable. The value of OR₂ indicates that when PM₁₀ was introduced into the model to adjust its impact on PM_{2.5}, while keeping other predictors unchanged, the logarithm of residential PM_{2.5} concentration was OR₂ times of the individual reference variable.

Abbreviations: CI=confidence interval.

environmental indicators such as temperature and humidity.

Outdoor PM_{2.5} was also a major contributor to residential particle concentrations (6), and the residential PM_{2.5} concentration showed an upward trend with an increase in altitude. This may be related to the vertical diffusion capacity of the atmosphere and the characteristics of the particulate matter, especially changes in wind speed at varying vertical heights (7). Household economic levels and average per capita area may also affect PM_{2.5} concentrations to some extent, which may be caused by lifestyle behaviors of family members (8). Some lifestyle habits were associated with the concentration of residential PM_{2.5}. Housekeeping activities, such as sweeping and vacuuming, were associated with increased concentrations of residential PM_{2.5} because household cleaning could possibly disturb deposited particles from domestic floors and furniture (8). The use of air purifiers and range hoods

might also reduce residential PM_{2.5} concentration to a certain extent (9).

This study was subject to several limitations. First, in cross-sectional studies, selection bias and information bias could be a problem even though households were selected randomly in each city. Secondly, some potential influencing factors of residential PM_{2.5} might be missed in this investigation due to the limited two times of sampling.

The findings highlighted the importance of an improvement plan for residential air quality. Public health supervision of residential PM_{2.5} pollution should be pushed forward according to the distribution pattern of PM_{2.5} in different cities. Additional information and incentives to eliminate residential PM_{2.5} pollution are needed urgently to guide healthier behavior in families.

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