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Impact of Air Pollution on Respiratory Diseases in Typical Industrial City in the North China Plain

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Abstract: Air pollution can lead to the elevated incidence of various respiratory diseases, seriously endangering the health of urban residents. To better comprehend the association between urban air pollution and respiratory disease incidence, this study focused on Xinxiang City, a typical industrial city in the North China Plain, as the research object. By analyzing monthly air pollution index concentrations from 2018 to 2021 and confirmed cases of respiratory diseases, and incorporating meteorological factors as reference points, we conducted a correlation analysis between disease data and pollutant concentrations. We then constructed a Poisson regression model to obtain maximum likelihood estimates, which were used to predict the quantitative relationship between the incidence of respiratory diseases and air pollution indicators. The results showed that an increase of 1 $\mu g/m^3$ in the average mass concentration of $PM_{2.5}$, PM_{10}, NO_2, and SO_2 in ambient air was associated with an elevated incidence of respiratory diseases by 0.2–1.4%, 0.7–1.6%, 3.7–8.2%, and 0.5–2.3%, respectively; meanwhile, a monthly mean mass concentration of CO increased by 1 mg/m^3 led to a rise in pulmonary tuberculosis incidence by 2.9%. Additionally, based on health risk data following exposure to air pollution in Xinxiang City, it was confirmed that the impact of respiratory diseases as measured by the air quality composite index was more applicable than the single pollution index. Furthermore, there was a significant association between air pollution and the incidence of respiratory diseases.

Keywords: air pollution; respiratory diseases; Poisson regression analysis; incidence rate

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1. Introduction

Environmental pollution is increasing in various ways and poses a threat to both the environment and human health. Urban areas are particularly vulnerable to increased concentrations of key pollutants, such as $PM_{2.5}$, PM_{10}, NO_2, SO_2, NO, CO, and O_3, due to factors such as industrial activities, traffic emissions, wildfires, and domestic heating [1,2]. These pollutants can cause short-term health risks. The WHO estimates that approximately 7 million people die each year due to diseases related to air pollution, such as lung cancer, pneumonia, chronic obstructive pulmonary disease (COPD), chronic respiratory diseases, and stroke [3,4]. Epidemiological studies have demonstrated the association between numerous illnesses and air pollution, particularly those affecting the respiratory system [5–8].

Since 2013, China has been plagued by severe air pollution, which is currently one of the primary ecological threats. Air pollution can lead to a variety of respiratory diseases and seriously harm the health of urban residents. Despite the implementation of a series of measures to control air pollution in recent years, pollutants such as $PM_{2.5}$ remain the main cause of declining air quality. Previous studies have demonstrated a positive correlation between rising concentrations of pollutants and the increased incidence of respiratory diseases [9–12]. For instance, Chen et al. demonstrated a significant correlation between $PM_{2.5}$, SO_2, CO, and NO_2 exposure and influenza risk in Jinan, China during the 2020–2021 period [13]. Song et al. found that high-level exposure to $PM_{2.5}$ was positively associated with the onset of chronic obstructive pulmonary disease in Shijiazhuang, China, and this effect could be modified by temperature and relative humidity [14]. Tao's team investigated the correlation between various air pollutants and hospitalization due to respiratory illnesses from 2001 to 2005 in Lanzhou, China [15]. The results revealed noteworthy associations between air pollution and hospital admissions related to respiratory diseases, with more pronounced effects observed among females and individuals aged over 65 years [15]. However, current research has a stronger focus on the Yangtze River Delta and Pearl River Delta regions and Beijing–Tianjin–Hebei [8,16–22], with limited attention given to the Central Plains Economic Zone and its main city of Xinxiang. Furthermore, the exposure–response relationships may vary between locations and cannot necessarily be applied to areas with differing socioeconomic statuses or levels of air pollution. Therefore, it is important to conduct further research in these underrepresented areas.

Xinxiang (35°18′11″ N, 113°55′34″ E) is located in the North China Plain and serves as a pivotal city situated at the heart of both the Central Plains Economic Zone and the core area of the Central Plains urban agglomeration. Xinxiang City is one of the "2 + 26" cities (encompassing Beijing, Tianjin, and 26 cities in Hebei, Henan, Shanxi, and Shandong Province) located in the air pollution transmission channel of the Beijing–Tianjin–Hebei region. In winter, Xinxiang's monsoonal characteristics include the prevailing northeasterly winds. With its swift economic development, urbanization, and population growth, Xinxiang has witnessed a significant surge in energy consumption and motor vehicle usage. Consequently, fine particulate matter pollution has emerged as a pressing issue regarding atmospheric contamination. Apart from local emissions, the input of air pollution may be accompanied by the northeastern monsoon through long-range transport from the heavily polluted Beijing–Tianjin–Hebei region. Consequently, an increase in air pollution has been observed over time in Xinxiang, particularly during winter periods. In recent years, studies have been conducted to investigate the pollution characteristics, health risks of heavy metals, and sources of $PM_{2.5}$ in Xinxiang City [23,24]. However, these studies were limited to $PM_{2.5}$ and did not consider the potential health impacts of other pollutants or their relationships with specific diseases. Therefore, it is necessary to urgently investigate the correlation between air pollutants and respiratory diseases in Xinxiang City for the protection of public health.

Limited research has been conducted on the correlation between air pollution and hospitalization in urban areas of Xinxiang City. This study conducted a preliminary analysis of the correlation between air pollutants and respiratory diseases. By collecting the monthly average mass concentrations of six conventional air pollutants ($PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO) and data on various confirmed cases of respiratory diseases in Xinxiang City from 2018 to 2021, we discussed the effects of air pollution on respiratory diseases while also assessing the predictive ability of the air quality composite index and single pollution index regarding health effects.

2. Data and Methods

2.1. Data Source

2.1.1. Respiratory Disease Data

According to the CA00-CB7Z classification of respiratory diseases in the International Classification of Diseases (ICD-11), this study selected asthma, bronchitis, upper respiratory tract infection (URTI), pneumonia, emphysema, COPD, and tuberculosis as the respiratory diseases. Monthly confirmed cases and total deaths for these seven types of respiratory diseases (from January 2018 to December 2021) were collected from the first affiliated hospital of Xinxiang Medical University (Xinxiang, Henan Province), which is a general hospital and represents the majority of hospital admissions in Xinxiang City.

2.1.2. Air Pollution Index Data

Based on the China Online Air Quality Monitoring Platform (https://www.aqistudy.cn/, accessed on 4 May 2022), this study collected the monthly average mass concentrations of $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO for Xinxiang City in China from January 2018 to December 2021.

2.1.3. Climatological Data

The monthly average temperature data for Xinxiang City from January 2018 to December 2021 were sourced from the China Weather Network (www.weather.cn, accessed on 4 May 2022), while the corresponding monthly precipitation (mm) data were obtained from the Geographic Remote Sensing Ecological Network (www.gisrs.cn, accessed on 4 May 2022).

2.2. Research Method

2.2.1. Air Quality Index Calculation

The individual index of each air pollutant was calculated as follows:

$$I_i = \frac{C_i}{S_i} \tag{1}$$

where C_i is the concentration value of pollutant i, and S_i is the secondary standard for the annual average concentration of pollutant i (the value of S_i is obtained from the Ambient Air Quality Standards, GB3095-2012) [25].

The air quality composite index was calculated as follows:

$$I_{sum} = \sum_i I_i \tag{2}$$

where I_{sum} is the air quality composite index, and I_i is the single index of pollutant i, which includes the indexes of all six conventional air pollutants ($PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO).

2.2.2. Correlation Analysis

Based on the monthly statistics of the air pollution indicators and the incidence of various respiratory diseases, Pearson correlation analysis was performed using the SPSS 24.0 software, using a one-tailed significance test with significance set using a p-value.

2.2.3. Regression Analysis

The number of confirmed respiratory diseases is a type of typical discrete data, which can only be used as non-negative integers. A discrete-type data distribution approximates a Poisson distribution. Therefore, we employed a Poisson regression model to analyze the short-term impact of the air pollution index on the incidence of respiratory diseases [26–28]. Poisson log distribution analysis was performed using the SPSS 24.0 software with 100 iterations. The specific model's form was as follows:

$$\log E(Y_t) = \mu + \varepsilon_t \tag{3}$$

$$E(Y_t|x) = e^{\theta x} = e^{\beta_0 + \beta_1 P_t + \beta_2 T_t + \beta_3 W_t} \tag{4}$$

where Y_t represents the number of confirmed cases in month t, x is the vector variable of the decision, and P_t, T_t, and W_t represent the monthly average concentration of air pollutants, monthly average temperature, and monthly precipitation, respectively.

In the Poisson regression model, θ can be estimated through maximum likelihood estimation, which involves identifying the value that maximizes the probability of θ based on the current observed value of Y. The number of confirmed respiratory disease cases with the highest probability given the prevailing air pollutants and meteorological data was obtained. The probability density function is expressed as

$$P\{Y = Y_t|x\} = \frac{[E(Y_t|x)]^Y \times e^{-E(Y|x)}}{Y_t^!} = \frac{e^{y\theta x}e^{-\theta x}}{Y_t^!} \quad (5)$$

3. Results and Discussion

3.1. Overall Status of Air Pollution and Respiratory Diseases in Xinxiang City

The annual average concentrations of $PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3, and CO in Xinxiang City from 2018 to 2021 were recorded as 52, 93, 39, 15, and 104 μg m^{-3} and 1.0 mg m^{-3}, respectively. In comparison with the WHO Global Air Quality Guidelines (AQG 2021) for the annual average concentrations of air pollutants [29], the values of $PM_{2.5}$, PM_{10}, and O_3 exceeded the WHO limit values (5, 15, and 60 μg m^{-3}, respectively). The NO_2 value was close to the value of the WHO (40 μg m^{-3}), while the values of SO_2 and CO were much lower than the values of the WHO (40 μg m^{-3} and 4 mg m^{-3}), respectively. Upon comparison, it is evident that PM remains the primary pollutant in Xinxiang City and that NO_2 and O_3 pollution should not be neglected.

From 2018 to 2021, there were a total of 32,025 respiratory hospital admissions at the three general hospitals. Over the study period, an average of 667 hospital admissions due to respiratory diseases per month occurred in Xinxiang City. The number of male hospitalizations was three times as great as that of female hospitalizations, and admissions for patients <60 y comprised one third of the total. The subgroups of the respiratory diseases, including asthma, URTI, pneumonia, COPD, and tuberculosis, accounted for 7.1%, 5.6%, 4.5%, 35.0%, 12.9%, and 34.4% of the total respiratory hospitalizations, respectively. Previous studies have indicated that air pollution is a primary contributor to respiratory diseases [6,7,12]. The analysis of air pollutant data from Xinxiang City between 2018 and 2021 suggests that PM pollution may be a significant factor contributing to the high incidence of respiratory diseases in Xinxiang city. Therefore, the relationship between respiratory diseases and air pollution should be analyzed.

3.2. Temporal Fluctuations in Ambient Air Pollution and Their Correlations with Respiratory Diseases

To comprehensively investigate the impact of air pollution on the respiratory health among residents in Xinxiang City, we analyzed inter-annual variations in both air pollution levels and the incidence of respiratory diseases. As depicted in Figure 1, the inter-annual trend of respiratory diseases exhibited a similar pattern to that of PM, with both experiencing an increase in 2019. Specifically, the concentrations of $PM_{2.5}$ and PM_{10} in Xinxiang City were recorded as 56 and 102 μg m^{-3}, respectively, surpassing the national average annual secondary standard [25] in 2019. Additionally, in 2019, the incidence of respiratory diseases in Xinxiang rose by 6.6% compared to the previous year, with $PM_{2.5}$ and PM_{10} levels increasing by 2.1% and 9.5%, respectively. However, other pollutants (SO_2, NO_2, O_3, and CO) showed a decreasing trend over the previous four years that did correspond to changes in respiratory disease rates. The overall incidence of respiratory diseases in Xinxiang during 2020–2021 was lower than that in previous years, which may be attributed to the preventive and control measures implemented during the COVID-19 pandemic. With the outbreak of COVID-19, mandatory mask wearing was implemented in public spaces throughout Xinxiang City, along with social distancing, diligent hand washing, and some public closures. These measures taken to mitigate COVID-19 may have helped to prevent respiratory diseases and reduce their occurrence.

The correlation between the total number of respiratory diseases and the seasons was also investigated, revealing a distinct seasonal pattern, as depicted in Figure 2. The highest incidence occurred specifically during winter, with 884 cases, while the lowest incidence was observed in autumn, with 545 cases. The five conventional air pollutants ($PM_{2.5}$, PM_{10}, NO_2, CO, and SO_2) exhibited similar seasonal patterns, with the highest concentrations occurring in winter and the lowest in summer. In addition, the average concentrations of air pollutants ($PM_{2.5}$, PM_{10}, NO_2, CO, and SO_2) during winter significantly exceeded those of the annual average concentrations. Xinxiang is a city located in Northern China and relies on winter heating during cold months (from November 15 and March 15). The elevated concentrations of the $PM_{2.5}$, PM_{10}, NO_2, and SO_2 pollutants in winter were primarily due to winter heating, especially the combustion of coal for heating purposes. Previous studies have found that the winter heating policy leads to higher pollution concentrations in Northern China [21,30,31]. Additionally, Zhou et al. reported that during winter in China, there is a statistically significant association between air pollution and respiratory mortality in northern cities; however, such an association is not observed in southern cities of China [8]. From a seasonal perspective, respiratory diseases share similar seasonal patterns with the $PM_{2.5}$, PM_{10}, NO_2, SO_2, and CO pollutants. This suggests that the reason for the increase in the incidence of respiratory diseases in winter is associated with elevated concentrations of air pollutants.

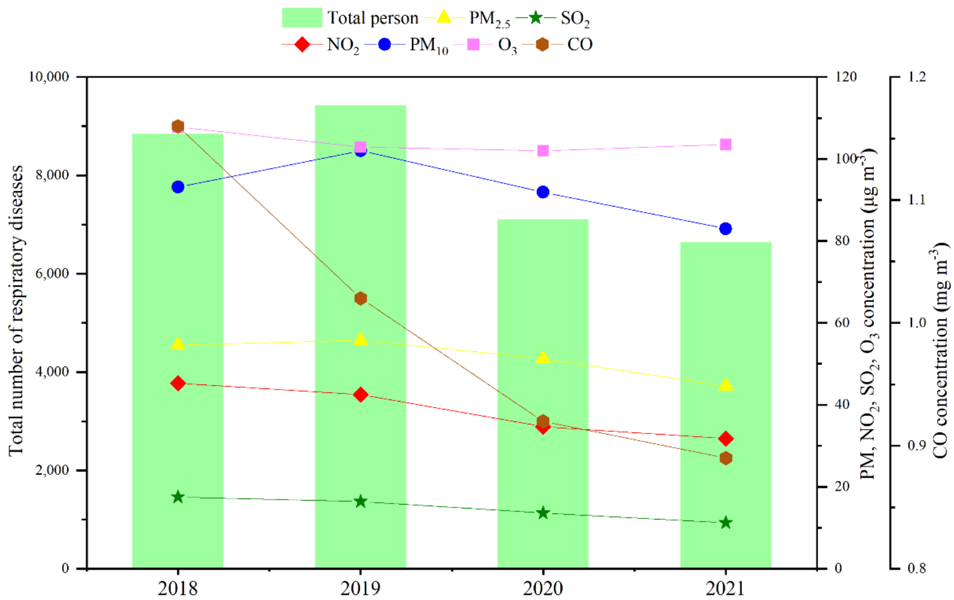

Figure 1. Trends in respiratory diseases and air pollutants from 2018 to 2021.

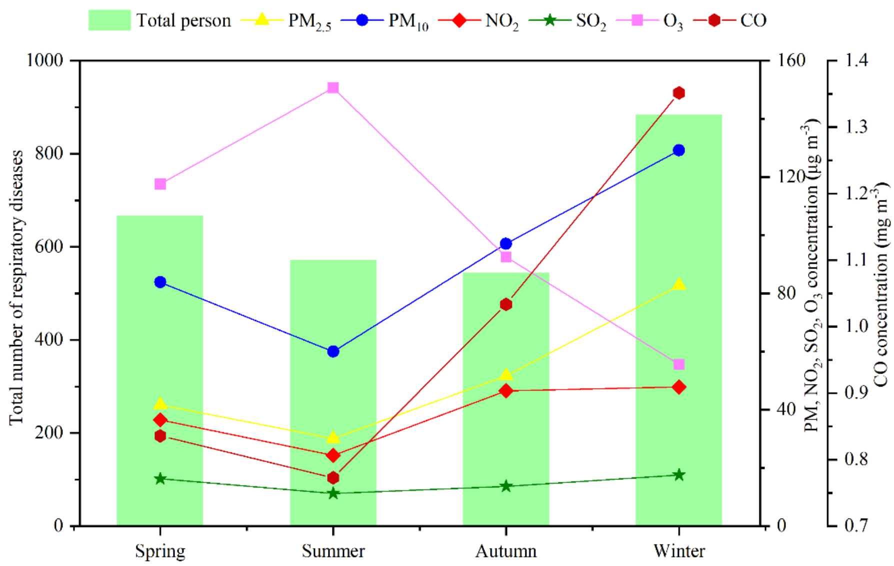

Figure 2. Seasonal fluctuations in air pollutants and their impact on respiratory illnesses.

Figure 3 illustrates the monthly variations in the six conventional air pollutants and respiratory diseases. As depicted in Figure 3, August had the lowest number of respiratory disease cases, which corresponded to the lowest concentrations of PM_{10} and $PM_{2.5}$. This suggests a significant reduction in particulate-matter-induced illnesses during this month. Conversely, January saw the highest number of cases, at 1077, indicating severe air pollution in Xinxiang City, with high levels of $PM_{2.5}$. This also indicates a rise in air pollutant emissions resulting from increased human activities, such as coal burning, during the winter in January, leading to an increase in respiratory diseases related to pollution [32].

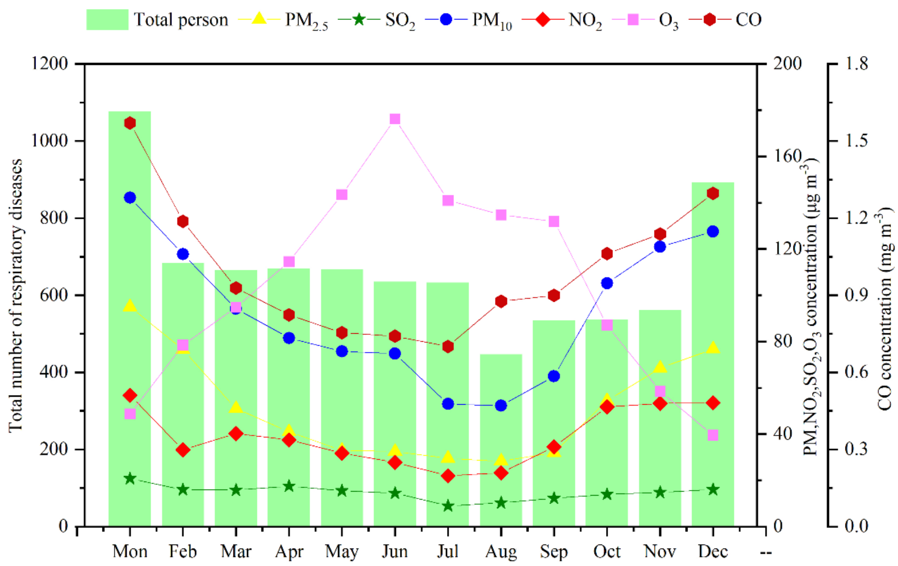

Figure 3. Monthly variations in air pollutants and their correlation with respiratory diseases.

3.3. Effects of Air Pollution on Respiratory Diseases

To further elucidate the impact of air pollutants on respiratory diseases among residents in Xinxiang City, the correlations between the incidence of respiratory diseases and multiple air pollutants were analyzed. As shown in Table 1, there was a significant and positive association between various respiratory diseases and air pollutants. Specifically, asthma, bronchitis, URTI, pneumonia, and COPD were significantly associated with air pollution indicators, with the exception of O_3. This was primarily due to the infiltration of pollutants into the bronchial and pulmonary systems through inhalation. Prolonged exposure to high concentrations of these air pollutants has resulted in the development of various respiratory diseases. Emphysema is positively associated with SO_2 concentrations, independent of the concentrations of other pollutants. Additionally, tuberculosis showed a significant positive association with NO_2 and SO_2. This is primarily attributed to the irritant and water-soluble nature of NO_2 and SO_2, which can damage the respiratory mucosa, facilitating mycobacterium tuberculosis' invasion into the lungs [33]. Furthermore, exposure to NO_2 and SO_2 may suppress tumor necrosis factor-α, γ-interferon, and interleukin-1β expression in alveolar macrophages, leading to the increased incidence of tuberculosis [34]. Furthermore, the air quality composite index demonstrated a noteworthy positive association with multiple respiratory diseases, surpassing all individual measures and exhibiting greater significance in the one-tailed test. Unlike other pollutants, O_3 levels are typically higher during the summer months and have a significant negative correlation with the monthly average concentrations of other pollutants in the air. Additionally, there was a negative association between O_3 levels and various respiratory diseases; thus, it does not serve as a direct cause of such illnesses [5].

Table 1. Correlation coefficients between air pollution index and respiratory diseases.

Pollution Parameter	Asthma	Bronchitis	URTI	Pneumonia	Emphysema	COPD	Tuberculosis	Number of Deaths
Air Quality Composite Index	0.450 **	0.644 **	0.443 **	0.709 **	0.092	0.646 **	0.200	0.465 **
	(0.001)	(0.000)	(0.001)	(0.000)	(0.267))	(0.000))	(0.091))	(0.000)
$PM_{2.5}$	0.281 *	0.573 **	0.417 **	0.757 **	−0.004	0.593 *	0.053	0.509 **
	(0.027)	(0.000)	(0.002)	(0.000)	(0.490)	(0.000)	(0.362)	(0.000)
PM_{10}	0.318 *	0.562 **	0.369 **	0.713 **	0.031	0.587 **	0.107	0.465 **
	(0.014)	(0.000)	(0.005)	(0.000)	(0.418)	(0.000)	(0.240)	(0.000)
CO	0.206	0.558 **	0.368 **	0.677 **	0.080	0.480 **	0.031	0.389 **
	(0.080)	(0.000)	(0.005)	(0.000)	(0.294)	(0.000)	(0.419)	(0.003)
NO_2	0.337 **	0.559 **	0.299 *	0.564 **	0.189	0.461 **	0.322*	0.316 *
	(0.009)	(0.000)	(0.020)	(0.000)	(0.099)	(0.000)	(0.014)	(0.014)
SO_2	0.515 **	0.587 **	0.410 **	0.494 **	0.307 *	0.657 **	0.549 **	0.310 *
	(0.000)	(0.000)	(0.002)	(0.000)	(0.017)	(0.000)	(0.000)	(0.016)
O_3	0.028	−0.373 **	−0.209	−0.613 **	0.000	−0.334 *	0.037	−0.364 **
	(0.424)	(0.005)	(0.077)	(0.000)	(0.499)	(0.010)	(0.405)	(0.006)

p values are presented in parentheses (* for $p < 0.05$, the correlation is significant; ** for $p < 0.01$, the correlation is extremely significant).

After conducting maximum likelihood estimation on the Poisson regression model, we obtained the coefficients of maximum likelihood estimation for each respiratory disease system with respect to each air pollution index and meteorological index. The model fitted with these coefficients reveals the relationship between the respiratory disease incidence, air pollution indicators, and meteorological factors. As presented in Table 2, asthma, bronchitis, URTI, pneumonia, COPD, and tuberculosis exhibit positive correlations with air pollutants, with the exception of O_3. The coefficients are significantly different from zero, indicating a strong association between air pollution and these diseases. Among them, pneumonia exhibits the strongest association with the air pollution indicators ($p < 0.01$) and is significantly associated with meteorological indicators.

Table 2. Maximum likelihood estimation for monthly average concentrations of pollution indicators and respiratory diseases.

Pollution Parameter	Asthma	Bronchitis	URTI	Pneumonia	Emphysema	COPD	Tuberculosis	Number of Deaths
$PM_{2.5}$	0.007 ** (0.000)	0.016 ** (0.000)	0.015 ** (0.000)	0.009 ** (0.000)	−0.001 (0.884)	0.008 ** (0.000)	0.001 (0.246)	0.007 (0.139)
Air Temperature	0.021 ** (0.000)	0.018 ** (0.000)	0.020 ** (0.001)	−0.024 ** (0.000)	−0.001 (0.980)	0.006 * (0.094)	0.017 ** (0.000)	−0.017 (0.309)
Amount of Precipitation	−0.002 ** (0.000)	−0.003 ** (0.002)	0.000 (0.665)	0.001 ** (0.003)	−0.001 (0.698)	−0.002 ** (0.000)	−0.001 ** (0.000)	0.001 (0.669)
Pollution Parameter	**Asthma**	**Bronchitis**	**URTI**	**Pneumonia**	**Emphysema**	**COPD**	**Tuberculosis**	**Number of Deaths**
PM_{10}	0.006 ** (0.000)	0.014 ** (0.000)	0.010 ** (0.000)	0.007 ** (0.000)	0.002 (0.807)	0.006 ** (0.000)	0.002 ** (0.009)	0.005 (0.255)
Air Temperature	0.019 ** (0.000)	0.011 ** (0.036)	0.010 * (0.079)	0.027 ** (0.000)	0.008 (0.741)	0.001 (0.746)	0.019 ** (0.000)	−0.023 (0.142)
Amount of Precipitation	−0.001 ** (0.025)	−0.001 * (0.064)	0.001 (0.100)	0.001 ** (0.000)	−0.001 (0.761)	−0.001 ** (0.000)	0.000 ** (0.009)	0.001 (0.441)

Table 2. *Cont.*

Pollution Parameter	Asthma	Bronchitis	URTI	Pneumonia	Emphysema	COPD	Tuberculosis	Number of Deaths
CO	0.347 ** (0.001)	1.335 ** (0.000)	0.758 ** (0.000)	0.510 ** (0.000)	0.527 (0.341)	0.397 ** (0.000)	0.029 ** (0.000)	0.094 (0.787)
Air Temperature	0.014 ** (0.002)	0.020 ** (0.000)	0.007 (0.239)	−0.031 ** (0.000)	0.019 (0.403)	−0.002 (0.469)	0.015 ** (0.000)	−0.033 ** (0.031)
Amount of Precipitation	−0.002 ** (0.000)	−0.004 ** (0.000)	−0.001 (0.138)	0.000 ** (0.331)	−0.001 (0.544)	−0.002 ** (0.000)	−0.001 ** (0.000)	0.001 (0.658)
Pollution Parameter	**Asthma**	**Bronchitis**	**URTI**	**Pneumonia**	**Emphysema**	**COPD**	**Tuberculosis**	**Number of Deaths**
NO_2	0.009 ** (0.000)	0.025 ** (0.000)	0.011 ** (0.000)	0.008 ** (0.000)	0.023 (0.057)	0.005 ** (0.005)	0.009 ** (0.000)	0.001 (0.935)
Air Temperature	0.010 ** (0.006)	−0.008 * (0.038)	−0.009 * (0.034)	−0.042 ** (0.000)	0.021 (0.262)	−0.012 ** (0.000)	0.021 ** (0.000)	−0.036 ** (0.003)
Amount of Precipitation	−0.001 * (0.022)	−0.001 (0.750)	0.001 (0.230)	0.001 ** (0.000)	0.001 (0.770)	−0.011 ** (0.001)	0.000 (0.683)	0.001 (0.592)
Pollution Parameter	**Asthma**	**Bronchitis**	**URTI**	**Pneumonia**	**Emphysema**	**COPD**	**Tuberculosis**	**Number of Deaths**
SO_2	0.037 ** (0.000)	0.082 ** (0.000)	0.057 ** (0.000)	0.031 ** (0.000)	0.081 ** (0.007)	0.050 ** (0.000)	0.038 ** (0.000)	0.020 (0.330)
Air Temperature	0.007 * (0.020)	−0.015 ** (0.000)	−0.010 ** (0.007)	−0.043 ** (0.007)	0.012 (0.455)	−0.009** (0.000)	0.018 ** (0.000)	−0.034 ** (0.002)
Amount of Precipitation	−0.001 (0.237)	0.000 (0.618)	0.001 ** (0.008)	0.002** (0.000)	0.001 (0.546)	0.00 (0.467)	0.000* (0.019)	0.001 (0.413)
Pollution Parameter	**Asthma**	**Bronchitis**	**URTI**	**Pneumonia**	**Emphysema**	**COPD**	**Tuberculosis**	**Number of Deaths**
O_3	0.006 ** (0.000)	0.003 (0.062)	0.004* (0.042)	0.003 ** (0.000)	0.000 (0.988)	0.008 ** (0.000)	0.000 (0.428)	0.008 (0.082)
Air Temperature	−0.024** (0.001)	−0.040 ** (0.000)	−0.033** (0.000)	−0.061 (0.000)	0.004 (0.915)	−0.053 ** (0.000)	0.012 ** (0.000)	−0.075 ** (0.002)
Amount of Precipitation	−0.001 * (0.068)	−0.002 (0.003)	0.000 (0.473)	0.001 (0.000)	−0.001 (0.714)	−0.001 ** (0.000)	−0.001 ** (0.002)	0.002 (0.281)
Pollution Parameter	**Asthma**	**Bronchitis**	**URTI**	**Pneumonia**	**Emphysema**	**COPD**	**Tuberculosis**	**Number of Deaths**
Air Quality Composite Index	0.355 ** (0.000)	0.750 ** (0.000)	0.555 ** (0.000)	0.362 ** (0.000)	0.256 (0.382)	0.367 ** (0.000)	0.135 ** (0.000)	0.269 (0.130)
Air Temperature	0.016 ** (0.000)	0.007 ** (0.000)	0.005 (0.277)	−0.032 ** (0.000)	0.012 (0.507)	−0.001 (0.818)	0.019 ** (0.000)	−0.025 (0.053)
Amount of Precipitation	−0.001 * (0.047)	−0.001 ** (0.000)	0.001 (0.070)	0.001 ** (0.000)	0.000 (0.885)	−0.001 ** (0.007)	0.000 (0.057)	0.001 (0.429)

p values are presented in parentheses (* for $p < 0.05$, the correlation is significant; ** for $p < 0.01$, the correlation is extremely significant).

The coefficient estimated by maximum likelihood for emphysema and multiple pollution indicators failed to meet the significance threshold of 0.05, indicating the lack of a statistically significant association between emphysema and air pollution indicators. The coefficient of maximum likelihood estimation for the number of deaths caused by respiratory diseases and various pollution indicators was found to be positive; however, none of them passed the significance test at the 0.05 level. Combined with the correlation analysis in Table 1, it was demonstrated that air pollution exacerbated respiratory conditions, albeit to a limited extent. No significant association between O_3 and multiple respiratory diseases was observed, consistent with the Pearson's correlation analysis; however, the maximum likelihood estimation coefficient exhibited a positive trend of greater magnitude than that of single contamination indices, indicating stronger correlations in testing. Based on the maximum likelihood estimation coefficient of Poisson regression, an increase of 1 μg/m^3 in $PM_{2.5}$, PM_{10}, NO_2, and SO_2 is associated with a respective increase in the incidence rates of respiratory diseases by 0.2–1.4%, 0.7–1.6%, 3.7–8.2%, and 0.5–2.3%. The incidence of pulmonary tuberculosis showed a 2.9% increase with each additional 1 mg/m^3 in the monthly average mass concentration of CO. In order to control for confounding variables, the monthly average temperature and monthly precipitation were incorporated into the regression analysis. The results of the Poisson regression indicated a significant association between respiratory diseases and air temperature, but not with precipitation.

4. Conclusions

Based on the air pollution monitoring data and synchronous conventional meteorological data from Xinxiang City between 2018 and 2021, the confirmed cases of various respiratory diseases were used as an effective index to quantitatively analyze the association between the monthly concentrations of various air pollutants and the incidence of human respiratory diseases in Xinxiang City. The study's results indicate a strong association between air pollution and respiratory diseases in Xinxiang City. A statistically significant association was observed between the $PM_{2.5}$, PM_{10}, NO_2, SO_2, and CO pollutants and the incidence of asthma, bronchitis, URTI, pneumonia, COPD, and tuberculosis. Furthermore, the exacerbation of air pollution significantly elevates the susceptibility to respiratory diseases. Based on the maximum likelihood estimation coefficient of the Poisson regression, an increase of 1 μg/m^3 in $PM_{2.5}$, PM_{10}, NO_2, and SO_2 is associated with a respective increase in the incidence rates of respiratory diseases by 0.7–1.6%, 0.2–1.4%, 3.7–8.2%, and 0.5–2.3%. The incidence of pulmonary tuberculosis showed a 2.9% increase with each additional 1 mg/m^3 in the monthly mean mass concentration of CO. Emphysema is largely unrelated to air pollution. In addition, consideration of the synergistic effects of multiple air pollutants on the respiratory disease incidence is a more objective approach than solely examining individual pollutants. The air quality composite index holds greater reference value in addressing respiratory diseases. This study confirms that improving the air quality in Xinxiang City will significantly benefit urban residents' health, reduce medical expenses related to respiratory diseases, and greatly enhance social welfare.

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