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Article

Analyzing the relationship between air pollution and asthma outpatient visits in Hefei through time series data

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Abstract: Objective: To examine the correlation between the volume of adult asthma patients seeking outpatient care and air pollution levels at a hospital in Hefei. **Methods**: Data on the number of asthma outpatients at a Hefei hospital from 2014 to 2020 were gathered, along with corresponding air pollution and meteorological data for the same timeframe. The R statistical software was employed to construct a generalized additive model to assess the lagged effects of air pollution on asthma outpatient numbers. **Results**: The hospital recorded a total of 7220 asthma outpatients during the study period, with 3104 males and 4116 females, 3798 in the warm season and 3422 in the cold season. The single pollutant model revealed that a 10% increase in SO_2 concentration $\mu g/m^3$ was associated with a 0.74% increase in asthma risk, with the strongest effect observed at lag2. NO_2 was found to increase asthma risk by 0.31%, with the most significant impact at lag0. The two-pollutant model indicated that the effect of SO_2 combined with NO_2 diminished when SO_2 was also combined with CO, O_3, PM_{10}, and PM_2, with an increased post-5 lag effect. Conversely, the effect of NO_2 combined with SO_2 decreased when NO_2 was also combined with CO, PM_{10}, and PM_2, with an increased post-5 lag effect. Stratified analysis by season showed that NO_2's impact on asthma was greatest at lag0 during the cold season, while SO_2's effect was more pronounced in the cold season than in the warm season, with the highest impact at lag2. Gender stratification analysis revealed that the effects of SO_2 and NO_2 were greater in men than in women. **Conclusion**: Between 2014 and 2020, an increase in SO_2 and NO_2 concentrations in Hefei was positively associated with the risk of asthma among outpatients at the hospital, with a noticeable lag effect. This finding underscores the importance of developing targeted preventive strategies to mitigate asthma occurrences and exacerbations.

Keywords: air pollution; asthma diseases; time series analysis; outpatient volume; generalized additive model

1. Introduction

In recent years, people realize that the rapid development of our country's air pollution has brought more and more serious. Studies have shown that direct exposure to air pollutants can cause lung damage [1,2], long-term exposure to air pollutants can cause a significant increase in the prevalence and incidence rate of asthma. Lead to shortness of breath, chest tightness, cough, and even death in serious cases. It is one of the most common reasons for patients to visit the respiratory department [3,4]. Air pollutants may cause certain harm or harmful impact on human beings, organisms and ecosystems [5]. Among them, a large amount of SO_2 and NO_2 in the atmosphere have damaged the earth's ecological environment and climate system, causing widespread concern of people all over the world.

According to a large number of literature [6,7], there are few quantitative analysis studies on air pollution, meteorological factors and outpatient volume of asthma diseases in China. In recent years, the incidence rate of asthma in Hefei is also increasing. The relationship between air pollution and meteorological factors on the outpatient volume of respiratory tract asthma has been studied in depth. The main purpose is to objectively evaluate the public health significance of air pollution and meteorological factors to people's health.

2. Materials and methods

Data source during the study period, the average values of 10 air monitoring stations in Hefei were selected to replace the exposure level of air pollutants of the research object. The meteorological data of the same period are obtained through China Meteorological Data Network (http://data.Cma.Cn), including daily average temperature, air pressure, wind speed, relative humidity, precipitation, sunshine time, etc. And systematically collect the daily treatment data of asthma clinic of a class III class a hospital in Hefei from 1 January 2014 to 31 December 2020, including disease diagnosis, gender, age, emergency date and other information. Classify and sort out the disease data, collect asthma outpatient cases, and the inclusion criteria: The selection of asthma cases meets the asthma diagnostic criteria of respiratory branch of Chinese Medical Association [8]; Eliminate respiratory diseases caused by accidental injuries. Adult patients over 16 years old were taken as the research objects, and the research objects were all local people in Hefei. According to the registered residence of the patient, the diagnosis of digestive system diseases, epilepsy, lymphadenitis and other cases were excluded.

Building model generalized additive model (GAM) is a traditional additive model proposed by stone. It is a model that can explain the nonlinear response relationship between influencing factors and corresponding variables [9]. It is one of the common models widely used in the research and application of air pollution or meteorological factors in the field of health. Therefore, this paper selects this model for exploration. It is a small probability event that patients go to the hospital clinic every day, and its real distribution is close to Poisson distribution. The study uses mgcv software package of R statistical software to establish a generalized additive model to explore the correlation between adult asthma outpatient volume and air pollution in a class III class a hospital in Hefei. The model is as follows:

$$\text{Log}\,[E(Yt)] = \alpha + \text{DOM} + \beta Xt + s(\text{time}, df) + s(Zt, df)$$

The specific meanings of each part in the above model are as follows: Y_t represents the asthma outpatient volume on day t; $E(Y_t)$ is the predicted asthma outpatient count on day t; A stands for intercept; β represents the regression coefficient; X_t represents the concentration of air pollutants on day t; Z_t is the meteorological data of day t; DOM is the dummy variable of cycle effect, and S is the smooth spline function of nonlinear variable. At the same time, establish single pollutant model and double pollutant model the single pollutant model includes one pollutant at a time, and the meteorological data are adjusted to evaluate the impact of short-term exposure to air pollution on the amount of asthma outpatients. Based on the single pollutant model, other pollutants are included in the model in turn. In the double pollutant model, only two pollutants are included at a time at the same time, the data of asthma clinic were analyzed according to cold and warm seasons and gender to study the correlation between air pollution and asthma clinic volume in different subgroups. According to the relevant research literature of GAM model [10], select the days within 5 detention days as the standard, and quote the one-day lag model to evaluate the impact of pollutants on asthma at different lag times [11].

Statistical analysis use Microsoft Excel software to establish data, and import the database into SPSS software and R software for statistical description and analysis. When describing the data, the mean, standard deviation, maximum value, minimum value and interquartile spacing are used. Spearman correlation is used to analyze the correlation between air pollutants and meteorological data. The excess risk (ER) and 95% confidence interval (95% CI) are used to represent every 10% increase of pollutants μ increase in the number of asthma patients in g/m^3 outpatient service.

3. Results

General description of pollutant data and meteorological data statistical description will be made between the concentration data and meteorological data of six air pollutants in Hefei from 1 January 2014 to 31 December 2020. The concentrations of 6 kinds of air pollutants are counted according to the warm season (May to October) and the cold season (November to April). The concentration of various pollutants fluctuated greatly from 2014 to 2020. Except that the concentration of O_3 in the warm season is higher than that in the cold season, the concentration of other pollutants increases in varying degrees in the cold season. The meteorological data shows that the average wind speed is 2 M/s; The average value of air pressure is 101.2 kPa; The average humidity is 76.8%; The average temperature is 16.7 °C (**Table 1**).

Table 1. Descriptive summary for daily air pollutants and meteorological factors in Hefei, China, during 2014–2020.

Variable	Mean value	Standard deviation	Minimum value	Interquartile spacing			Maximum
				P_{25}	P_{50}	P_{75}	
Contaminants							
$PM_{2.5}$ (μg/m^3)	55.7	36.5	4.6	31	47	71.4	359.8
O_3 (μg/m^3)	87.3	45.4	4	51.7	79	118.1	263.4
CO (μg/m^3)	0.9	0.3	0.3	0.7	0.8	1	2.9
PM_{10} (μg/m^3)	81.3	44.1	6.1	50	74	103.7	365.3
NO_2 (μg/m^3)	40.1	18.5	7.6	26.8	35.5	50	135.1
SO_2 (μg/m^3)	11.9	7.8	1	6	10	15.4	63.7
Warm season							
$PM_{2.5}$ (μg/m^3)	41.5	25.0	4.6	24.8	36.9	52.2	263.2
O_3 (μg/m^3)	106.8	46.0	13.9	263.4	68.0	107.0	139.0
CO (mg/m^3)	0.8	0.2	0.2	0.6	0.8	0.9	2.0
PM_{10} (μg/m^3)	71.7	40.7	9	45.2	64.7	89.8	323.5

NO_2 (μg/m^3)	33.8	14.2	7.6	24.0	31.0	40.0	102.3
SO_2 (μg/m^3)	9.4	5.5	1	5.0	8.9	11.7	52.2
Cold season (μg/m^3)							
$PM_{2.5}$	70.1	40.6	11.0	41.0	62.0	88.7	359.8
O_3 (μg/m^3)	67.5	35.1	4.0	40.0	62.0	88.3	208.0
CO (μg/m^3)	1.0	0.4	0.2	0.7	0.9	1.2	2.9
PM_{10} (μg/m^3)	91.0	45.3	6.1	58.0	86.0	115.9	365.3
NO_2 (μg/m^3)	46.5	20.2	10.0	31.9	43.0	58.2	135.1
SO_2 (μg/m^3)	14.4	8.9	1.0	7.0	13.0	19.5	63.7
Meteorological factors							
Air pressure (kPa)	101.2	1.0	98.8	100.4	101.3	102.0	104.1
Wind speed (M/s)	2.0	0.8	0.3	1.4	1.9	2.4	6.2
Relative humidity (%)	76.8	12.6	33.0	69.0	78.0	86.0	100.0
Temperature (°C)	16.7	9.2	-5.9	8.6	17.5	24.5	35.6

Note: the warm season refers to May to October and the cold season refers to November to April.

Correlation analysis of air pollutants and meteorological factors in Hefei from 2014 to 2020 Spearman correlation analysis of air pollutants and meteorological factors in Hefei. There is a certain correlation between air pollutants and meteorological factors.

General description of asthma outpatient data from 1 January 2014 to 31 December 2020, there were 7220 asthma outpatient cases in a third class hospital in Hefei, including 3104 male patients and 4116 female patients. There are 3798 asthma outpatients in the warm season. There were 1643 male patients, 2155 female patients and 3422 cold season patients, including 1461 male patients and 1961 female patients.

Single pollutant model results from 2014 to 2020, there was significant difference between the increase of SO_2 and NO_2 concentrations in Hefei and the increase of excess risk of asthma outpatients in a hospital in Hefei ($P < 0.05$) (**Table 2**).

Table 2. Excess risk (ER) and its 95% confidence intervals (95% CI) of daily asthma outpatients associated with 10 μg/m^3 increase in pollutants' concentrations for different lag days in single-pollutant models.

Contaminants	Lag(days)	ER	95% CI	Contaminants	Lag(days)	ER	95% CI
$PM_{2.5}$	0	0.03	(0.12~0.06)	NO_2	0	0.31	(0.13~0.49)***
	1	0.07	(0.02~0.15)		1	0.27	(0.11~0.43)***
	2	0.01	(0.07~0.10)		2	0.19	(0.04~0.34)
	3	0.02	(0.06~0.11)		3	0.11	(0.04~0.26)
	4	0.03	(0.11~0.06)		4	0.09	(0.05~0.24)
	5	0.10	(0.19~0.02)		5	0.05	(0.10~0.20)
PM_{10}	0	0.02	(0.09~0.05)	CO	0	0.02	(0.08~0.12)
	1	0.04	(0.03~0.10)		1	0.06	(0.03~0.16)
	2	0.02	(0.05~0.08)		2	0.07	(0.02~0.16)
	3	0.01	(0.05~0.07)		3	0.03	(0.06~0.12)

	4	0.02	(0.04~0.08)		4	0.03	(0.06~0.13)
	5	0.04	(0.10~0.02)		5	0.03	(0.12~0.06)
SO_2	0	0.43	(0.15~1.05)	O_3	0	0.02	(0.11~0.06)
	1	0.71	(0.17~1.28)**		1	0.00	(0.07~0.08)
	2	0.74	(0.22~1.29)**		2	0.02	(0.09~0.06)
	3	0.47	(0.03~1.00)		3	0.02	(0.09~0.05)
	4	0.50	(0.01~1.02)		4	0.04	(0.10~0.03)
	5	0.11	(0.38~0.63)		5	0.04	(0.11~0.03)

Note: ***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.

Based on the single pollutant model, the results of the double pollutant model are included in other pollutants respectively. In the two pollutant model, the effect decreases after SO_2 is incorporated into NO_2, and the effect decreases when CO, O_3, PM_{10} and $PM_{2.5}$ are incorporated. The post-5 effect increases. After NO_2 is incorporated into SO_2, the effect decreases, and CO, PM_{10} and $PM_{2.5}$ are incorporated. The post-5 effect increases. The effect remains unchanged after NO_2 is incorporated into O_3 (**Table 3**). The double pollutant model can test the stability of the model, and its results are consistent with the single pollutant model, so the stability of the model is good.

Table 3. Excess risk (ER) and its 95% confidence intervals (95% CI) of daily asthma outpatients associated with 10 μg/m^3 increase in pollutants' concentrations for different lag days in two-pollutant model.

Contaminated	**Model**	**Asthma**		**Contaminated**	**Model**	**Asthma**	
		ER	**95%CI**			**ER**	**95%CI**
SO_2	Single	0.74	(0.22–1.29)**	NO_2	Single	0.31	(0.13–0.49)***
	$PM_{2.5}$	0.82	(0.28–1.39)**		SO_2	0.30	(0.11–0.49)***
	NO_2	0.63	(0.10–1.18)**		$PM_{2.5}$	0.40	(0.19–0.61)***
	PM_{10}	0.79	(0.27–1.35**		PM_{10}	0.48	(0.25–0.70)***
	O_3	0.75	(0.23–1.30)**		O_3	0.31	(0.13–0.49)***
	CO	0.76	(0.22–1.32)**		CO	0.41	(0.19–0.64)***

Note: ***$P < 0.001$, **$P < 0.01$, *$P < 0.05$.

Subgroup analysis

Seasonal stratification results the whole year is divided into warm season (may~October) and cold season (November~April of the next year). The impact of the increase of air pollutants on the risk of outpatient asthma in different seasons is analyzed.

Figure 1 shows every 10% increase in SO_2 concentration μg/m, the comparison of the effects of different lag days (lag0–lag5) on asthma outpatient volume in cold season and warm season is shown as ER and its 95% CI range, in which the left represents cold season and the right represents warm season. The ER value reaches the maximum in lag2 in cold season, and there is no significant difference in the effect of pollutant concentration on asthma outpatient volume in warm season ($P >$ 0.05).

Figure 2 shows every 10% increase in NO_2 concentration μAt g/m, the comparison of the effects of different lag days (lag0–lag5) on asthma outpatient volume in cold season and warm season is shown as ER and its 95% CI, in which the left represents the cold season, the right represents the warm season, the cold season is lag0, and the effect of Lag3 on asthma outpatient volume is statistically significant. The ER value reaches the maximum in lag0, and every 10% increase in NO_2 concentration in warm season μ there was no significant difference in the effect of g/m on the outpatient volume of asthma ($P > 0.05$).

Gender stratification results explore different gender sensitive groups through gender stratification analysis.

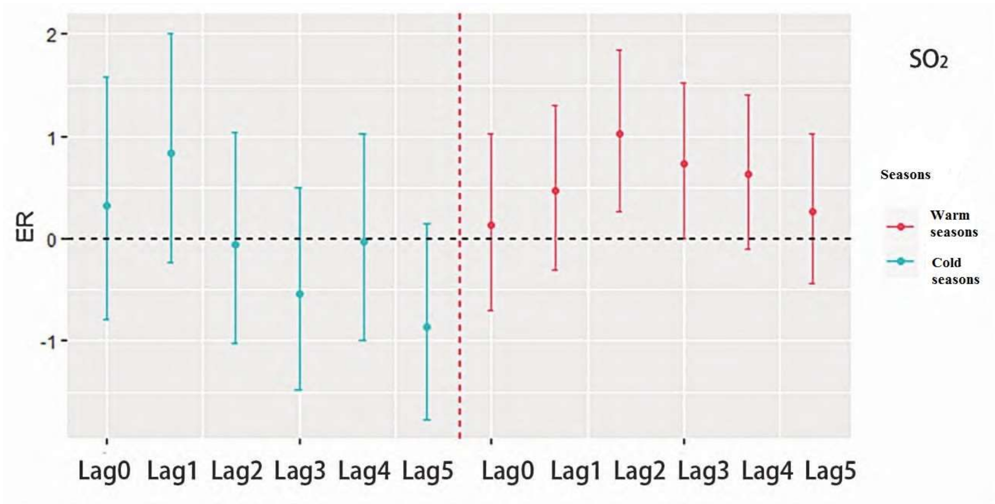

Figure 1. The excess risk (ER) and its 95% confidence interval (95% CI) of asthma outpatients for residents with a rise of 10 μg/m^3 in SO_2 in the cold and warm seasons with a lag of 0–5 days.

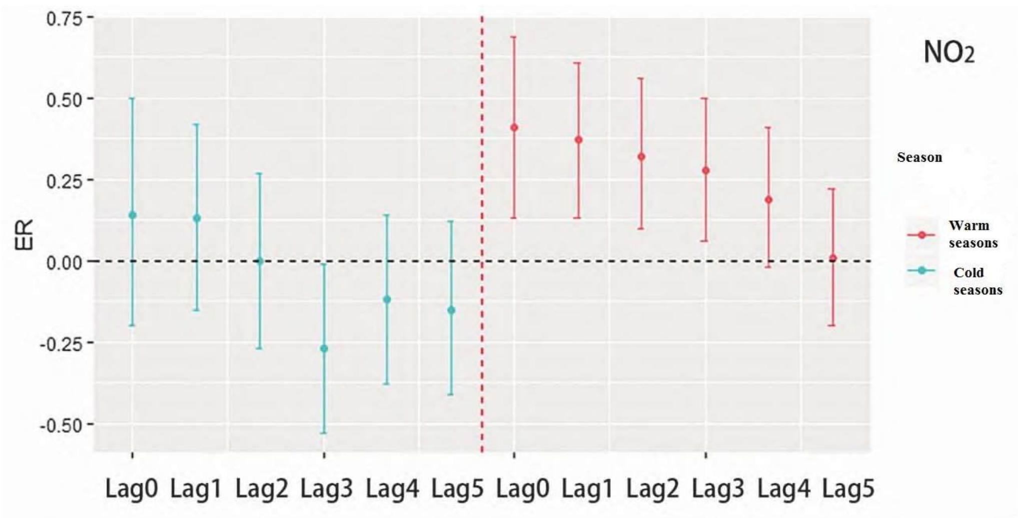

Figure 2. The excess risk (ER) and its 95% confidence interval (95% CI) of asthma outpatients for residents with a rise of 10 μg/m^3 in NO_2 in the cold and warm seasons with a lag of 0–5 days.

Figure 3 shows that every 10% increase in SO_2 concentration μg/m, the impact on the risk of asthma in men and women is shown as ER and its 95% CI range, in which the left represents women and the right represents men, and the ER value reaches the maximum among men There was no significant difference in the effect on female asthma ($P > 0.05$).

Figure 4 shows that every 10% increase in NO_2 concentration μg/m, the impact on asthma risk of men and women is shown in ER and its 95% CI range, in which the left represents women and the right represents men. The ER value reaches the maximum in lag0 for men and Lag1 for women. In lag0, lag2 and NO_2, there were significant differences in the impact of men on the risk of asthma ($P < 0.05$), and the ER value was higher than that of women.

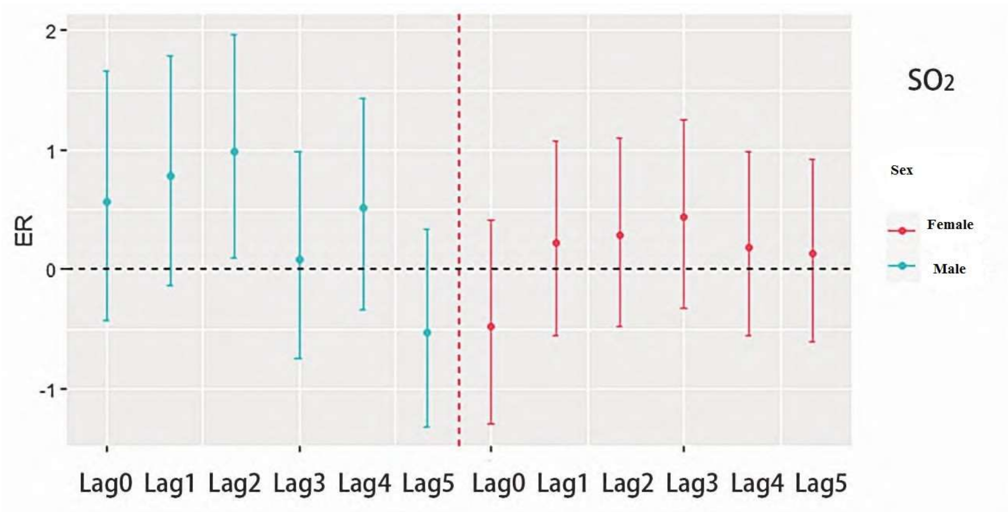

Figure 3. The excess risk (ER) and its 95% confidence interval (95% CI) of asthma outpatients for residents with a rise of 10 μg/m^3 in SO_2 for female and male with a lag of 0–5 days.

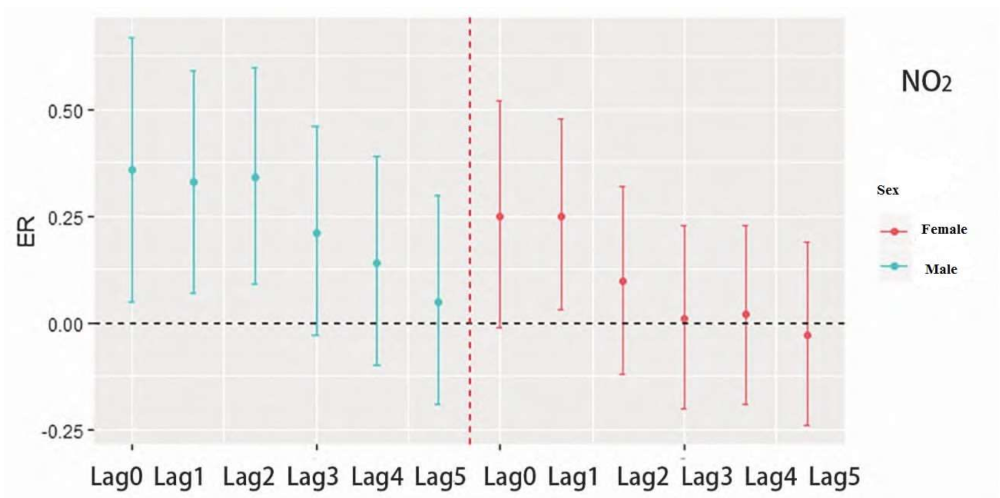

Figure 4. The excess risk (ER) and its 95% confidence interval (95% CI) of asthma outpatients for residents with a rise of 10 μg/m^3 in NO_2 for female and male with a lag of 0–5 days.

4. Discussion

Exercise enters the airway and deposits in the respiratory tract, resulting in the decline of pulmonary ventilation function and acute and chronic respiratory diseases [12–15]. Air pollution will make the respiratory system the target organ of air pollutants. Pollutants will produce more allergens in the breathing air, so it has a great impact on asthma.

Some studies have found that air pollution is positively correlated with the number of outpatients with asthma [16,17]; The generalized additive model was used to analyze the time series relationship between meteorological factors, air pollution and the number of patients with asthma. The results show that there are different degrees of correlation between meteorological factor indexes and pollutants in Hefei from 2014 to 2020, and the difference is statistically significant. In order to determine the relationship between the concentrations of six air pollutants and the daily outpatient volume of asthma, the time series analysis model was used to establish single pollutant and double pollutant models to analyze the relationship between the concentrations of pollutants and the daily outpatient volume of asthma; Stratified analysis according to season, and gender the study selected the number of days within 5 detention days as the standard study. The results of the single pollutant model showed that the concentration of so and no increased by 10 $\mu g/m^3$, the risk of outpatient asthma increased by 0.74% and 0.31% respectively, and the effect was the largest on lag2 day and the same day (lag0); The two pollutant model found that: SO_2 and NO_2 adjust other air pollutants CO, PM_{10} and $PM_{2.5}$ respectively. The post effects have increased Seasonal stratification analysis found that the effects of air pollutants SO_2 and NO_2 on the risk of asthma from November to April were higher than those from May to October, and there were different lags; it may be related to the stimulation of cold air to the airway. Stratified analysis of gender shows that men are more likely to develop asthma under the action of air pollutants SO_2 and NO_2. The study not only provides epidemiological basis for evaluating the impact of air pollution on respiratory health, but also has certain theoretical significance and practical value for evaluating the disease burden of people. At the same time, there are also limitations and deficiencies. The asthma clinic data collected in the study are only from a general hospital in Hefei. The sample size is not large enough and the research time is limited, so there may be selection deviation. The research data has limitations and cannot avoid the interference and influence of a variety of mixed factors such as health status, living habits and quality of life. In addition, smoking, decoration and oil fume are also important causes of many diseases. Therefore, when evaluating personal exposure dose, the impact of indoor air pollution is not considered because indoor air pollution data cannot be obtained. In the future, research methods should be improved and more reasonable quantitative evaluation standards should be designed.

In conclusion, the increase of air pollutants in Hefei may lead to the increase of the number of adult respiratory asthma clinics, and there is a certain lag effect. Therefore, it is necessary to further strengthen monitoring, reduce pollutant emission and protect residents' health.

Conflict of interest: The authors declare no conflict of interest.

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