The Effect of Air pollution on the Hospitalization for AECOPD

Cai Chen¹, Xiyuan Li¹, Xiangwei Meng¹, Zhixiang Ma¹, Wei Li¹, *, Dedong Ma², ³, a
¹Biomedical Engineering Institute, School of Control Science and Engineering, Shandong University, Jinan, China
²Dept. of Pulmonary and Critical Care Medicine, Qilu Hospital Shandong University, Jinan, China
³NHC Key Laboratory of Otorhinolaryngology (Shandong University), No. 44 Wenhuaxi Road, Jinan 250012, PR. China
*Corresponding author e-mail: cindy@sdu.edu.cn, amdd@sdu.edu.cn

Abstract. More evidences showed that there was a relationship between air pollution and hospitalization of acute exacerbation of chronic obstructive pulmonary disease. This paper aimed to investigate the effect of air pollution (fine particulate matter, inhalable particle, sulfur dioxide, nitrogen dioxide and ozone) on the hospitalization for acute exacerbation of chronic obstructive pulmonary disease. Thus, generalized additive model was built to evaluate the impact of air pollution on people’s respiratory system. After controlling for temperature and relative humidity, the increase in average daily concentrations of PM₂.₅, PM₁₀ and O₃ would aggravate the risk of admission of patients with acute exacerbation of chronic obstructive pulmonary disease, and the results were statistically significant.

1. Introduction
More and more evidence shows that air pollution is an important and critical risk factor for the increased incidence and mortality of respiratory diseases, cardiovascular diseases and cerebrovascular diseases [1-5]. With the rapid development of industrialization and economic growth in the past decades, air pollution in China has been a growing concern of the public issue. In recent years, atmospheric phenomena caused by dust (haze, high concentration of smog and other pollution particles) have occurred frequently in China. With the increasing population, China's society has gradually entered the aging stage, and with the acceleration of urbanization, industrialization and regional economic integration, the air pollution type in China is changing from single and local urban air pollution to regional and compound air pollution [6]. Because the energy structure of China was mainly based on fuel combustion [7]. Thus, heavy air pollution has taken place.

Chronic obstructive pulmonary disease (COPD) is a common airway disease [8]. Acute exacerbation of chronic obstructive pulmonary disease (AECOPD) is a vital event in the management of COPD, which will not only reduce the quality of life of patients, but also increase the rate of hospitalization and re-hospitalization, accelerate the progression of the disease, and significantly reduce lung function. Large-scale studies conducted in China have shown a significant relationship between air pollutant concentration and acute exacerbation of COPD. A study carried out in Taiwan...
using poisson regression method, the analysis of chronic obstructive pulmonary diseases acute exacerbation and PM2.5, the results showed that in the model for single pollutant, winter pm10 concentration increase (including 10 g/m3 (moving average lag 1), the admission rate of acute exacerbation of chronic obstructive pulmonary disease will increase 1.02 times (95% CI = 1.007-1.040);In model more pollutants, control of O3 and NO2, winter pm10 concentration increase (including 10 g/m3 (moving average delay) 1, AECOPD admission rate will increase 1.02 times (95% CI = 1.001-1.042), the results show that the similar study PM2.5 for hospitalized patients with chronic obstructive pulmonary diseases acute exacerbation rate is very stability, the influence of significant results [10].

This paper purposed to investigate the effect of air pollution (fine particulate matter, inhalable particle, sulfur dioxide, nitrogen dioxide and ozone) on the hospitalization for AECOPD.

2. Method and Meterails
In this study, patients admitted to Qilu Hospital of Shandong University due to acute exacerbation of COPD were selected as the investigation objects, and the hospitalization information of the patients was collected, including age, gender, admission time, discharge time, clinical symptoms, disease classification, residence, workplace and current residence. The hospital electronic medical record information system was adopted to export the data, and the data exclusion criteria were as follows: 1) patients whose current residence and workplace are not in Jinan;2) patients under the age of 18;3) patients admitted twice within one week;4) patients who repeatedly record data. Average daily concentration data of air pollutants in Jinan were collected from the environmental protection bureau of Jinan. The included pollutants included PM2.5 (g/m3), PM10 (g/m3), SO2 (g/m3), NO2 (g/m3) and O3. Meteorological data of the same period were collected from Jinan meteorological bureau, and included meteorological data indexes included average daily temperature (°C) and relative humidity (%). Generalized additive model (GAM) was first proposed by Hastie and Tibshirani in 1990 [11]. It is a generalized linear model with a linear predictor. It is used to fit and estimate the relationship between independent variables and dependent variables in a non-parametric form. Different from generalized linear model, GLM focuses on the estimation and inference of parameters in the model, while generalized additive model focuses on the exploration of non-parametric data, which is suitable for exploring the relationship between data and explaining the relationship between independent variables and dependent variables [12-14]. In the generalized additive model (GAM), the response variable is exponential. In order to understand the generalized additive model, the exponential additive function is introduced first.

2.1. Exponential distribution function
If the probability distribution or probability density of random variable Y is as follows (1),

$$f(y | \theta, \vartheta) = e^{\frac{y \vartheta - b(\vartheta)}{a(\vartheta)} + c(y, \vartheta)}$$

Where, $\vartheta$ is a scale parameter, $\theta$ called natural parameter, and $a(\cdot), b(\cdot)$ and $c(\cdot)$ is an arbitrary function, thus Y obeys exponential family distribution. For the exponential distribution of poisson distribution, letting the probability density function of Y, was as follows (2):

$$P(Y = y) = \frac{\mu^y}{y!} \exp(-\mu) = \exp(y \ln \mu - \mu - \ln(y!)), y = 0, 1, 2, \cdots$$

It can be seen that Y obeys exponential distribution, where $\theta = \ln \mu, b(\theta) = \mu, a(\vartheta) = 1$ and $c(y, \vartheta) = -\ln(y!)$. 

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2.2. Generalized additive model

In this study, the following semi-parametric generalized additive model was constructed (3). Where, \( Y_t \) represents the number of hospitalized patients on day \( t \); \( E(Y_t) \) represents the expected number of hospitalized patients on day \( t \) or Lag (t); \( \hat{C}_i \) represents the average daily concentration of pollutants on the day of \( t \) or Lag (t). Ns stands for natural spline smoothing function; Temp represents the average daily temperature; RH stands for relative humidity; Df represents freedom; Time represents the long-term trend of date; Dummy variables DOW and Holiday represent the "day of the week effect" and statutory holidays respectively, and \( \beta_2 \) and \( \beta_3 \) represent the coefficients of factor variables DOW and Holiday respectively.

\[
\begin{align*}
\log\left[ E(Y_t) \right] &= \alpha + \beta_1 C_i + ns(\text{Temp}, df) + ns(\text{RH}, df) + ns(\text{Time}, df) \\
&+ \beta_2 \text{factor(DOW)} + \beta_3 \text{factor(Holiday)}
\end{align*}
\]

3. Results

3.1. Descriptive Result

During the study period, the average annual temperature in Jinan was 15.2°C (-9.4°C ~ 33.7°C), and the average annual relative humidity was 56% (15% ~ 100%). The average annual concentrations of pollutants in Jinan were PM2.5 (94 mug/m³, 94 ~ 417 mug/m³), PM10 (188 mug/m³, 33 ~ 666 mug/m³), SO2 (79 mug/m³, 12 ~ 409 mug/m³), NO2 (57 mug/m³, 19 ~ 165 mug/m³), O3 (104 mug/m³, 11 ~ 261 mug/m³). The annual concentration of pollutants in Jinan is 2.7 times, 2.7 times, 1.3 times, 1.4 times and 0.7 times of the second-level limit (GB 3095-2012) of the national ambient air quality standard: PM2.5 (35 mug/m³), PM10 (70 mug/m³), SO2 (60 mug/m³), NO2 (40 mug/m³) and O3 (160 mug/m³), respectively.

3.2. Results of GAM

The results of generalized additive model was shown in Fig 1.
After controlling for temperature and relative humidity, the increase in average daily concentrations of PM2.5, PM10 and O3 would aggravate the risk of admission of patients with acute exacerbation of COPD, and the results were statistically significant. SO2 and NO2 had no effect on the risk of admission in patients with acute exacerbation of COPD, and the results were not statistically significant. The best Lag days of PM2.5 were Lag 3 days, and the best accumulated Lag days were Lag 03 days, with RR values (95%ci) of 1.031 (1.017-1.044) and 1.029 (1.018-1.040), respectively. The best Lag days of PM10 were Lag day 2, and the best cumulative Lag days were Lag day 02, with RR values (95%ci) of 1.016 (1.070-1.025) and 1.020 (1.009-1.031), respectively. The optimal Lag days of O3 were Lag 3,
and the optimal cumulative Lag days were Lag 03, with RR values (95%CI) of 1.028 (1.026-1.030) and 1.035 (1.031-1.039), respectively.

4. Discussion
Most previous studies have focused on estimating the overall incidence and mortality of air pollutants in the respiratory system, and few studies have assessed the risk of admission in patients with acute exacerbation of COPD alone [15]. The results showed that after controlling for temperature and relative humidity, PM2.5, PM10 and O3 increased the risk of admission of patients with acute exacerbation of COPD, while SO2 and NO2 had no effect on the risk of admission of patients with acute exacerbation of COPD. In addition, this study also found that PM2.5, PM10 and O3 had no same-day effect on admission of patients with acute exacerbation of COPD. This could be due to three air pollutants that are less soluble and reach deep into the lungs when inhaled. And these three kinds of air pollutants are highly active oxidant, high concentration will cause inflammation of respiratory epithelial cells. However, airway inflammation caused by oxidants still requires a certain reaction time, so it shows a cumulative effect rather than a day effect [16, 17].

Acknowledgments
This study was supported in part by grants from the National Natural Science Foundation (#21728701), the ministry of education postdoctoral fund (#2015M572044), Shandong Province Science and Technology Development Project (#GG201709260070); *Corresponding author: Wei Li, cindy@sdu.edu.cn; Dedong Ma, mdd@sdu.edu.cn.

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