*Research article*

AMBIENT AIR POLLUTION (PM10, NOx, and O3) AND VISIT OF ASMA PATIENTS IN JAKARTA 2017

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**Abstract**: Asthma is a common disease in the world, and it affects all types of races, ages, and genders. In 2017 asthma attacks 300 million people in the world. One risk factor for asthma is air pollution. The design of this study is a time stratified case-crossover, with secondary data types consisting of asthma visit data (ICD-10: J45) and pollutant data (PM10, O3, and NOx) in Jakarta 2017. The results from this study: NOx correlates with asthma patient visits with p <0.05 and r = 0.178. Ozone exposure lag day 3 p = 0.04, OR = 1.0016 (95% CI 1,0001-1.003) and lag day 1 of NOx exposure p = 0.04, OR = 1.0050 (95% CI 1 , 0003-1,010) which influences the visit of asthma patients in Jakarta. It will estimate that asthma patient visits will increase three days after ozone exposure or one day after NOx exposure. The conclusion that ozone and NOx have an association with asthma patient visits in Jakarta and this study PM10 pollutant did not show any relationship with patient visits due to asthma in Jakarta. Potential pollutants to be risk factors for asthma attacks will determinate by the level, time of exposure, effective dose, composition, and components of pollutants.

**Keywords**: Air pollution, Asthma, Jakarta, Pollutants

1. **Introduction**

Air pollution is the biggest threat and is one of the killers at the moment. According to the World Health Organization (WHO) data in 2015 air polluted by pollutants caused 6.4 million deaths worldwide. Ambient air pollution causes around 4.2 million deaths. [1-3] An estimated economic loss due to air pollution is 21 billion US dollars (USD). [1.4] Global Burden Disease (GDB) 2015 identifies air pollution as a major cause of the global disease burden, especially for low and middle-income countries. [5] In 2015, there were an estimated 6.4 million deaths due to air pollution with a disease burden of 167 million (95% UI 148-185 million) Disability-Adjusted Life Years (DALYs). Total In 2015 in Indonesia the number of deaths caused by air pollutants was 78,600 deaths (95% UI 62,000-92,700) with a disease burden of 1.08 million DALYs (95% UI 884,000-1,322,700). [5,6]

Air pollution is a risk factor for diseases of the respiratory system, nervous system, cardiovascular system, reproductive system (exposure during pregnancy), digestive system, and urinary system. Several studies have found that pollutants are a risk of lung cancer, asthma, chronic obstructive pulmonary disease, ischemic heart disease, and stroke. [7,8] Epidemiological studies show that there is a relationship between air pollution and poor air quality with asthma attacks, which leads to an increase in the prevalence of hospital visits, wheezing, and reduced lung function. [9,10] Asthma is a health disorder in the respiratory system that can be caused by exposure to air pollution. Asthma epidemics occur in countries with lower middle income. Environmental changes are considered as the biggest cause of asthma epidemics, especially exposure to air pollution-related to traffic. [11,12] The Global initiative of asthma (GINA) reports that in 2017, its estimate that asthma attacks around 300 million people in the world. Asthma attacks are more common in urban areas and are increasing in developing countries. [13.14]

Asthma is a disease that is underdiagnosed throughout the world. Asthma has a non-typical clinical picture and varying severity, as well as episodic symptoms. An asthma diagnosis is a base on episodic symptoms, symptoms such as coughing, shortness of breath, wheezing, wheezing in the chest, and weather-related variability. [15] Investigations to diagnose asthma include pulmonary physiology examination with a spirometer, examination of expiratory peak flow with a peak flow rate meter, reversibility test with a bronchodilator, bronchial provocation test, allergy test, and chest radiograph. Other important information needed is family history, allergic history, other illnesses, and the presence or absence of treatment. [16]

The World Health Organization (WHO) estimated in the year 2000 that around 800,000 deaths caused by exposure to particulates due to air pollution. [17] Data in 2016 as many as 92 % of the human population live and live in places with air quality that is not appropriate and exceeds the limits or air quality standards issued by WHO. [18,19] World Health Organization (WHO) determines several types of pollutants as indicators of air quality, including ozone (O3), Particulate Matter (PM), and NOx. [20]. Composition Particulate matter (PM) is a mixture of solid and liquid particles originating from various sources. Particulate matter (PM) divided into three based on the size of its diameter, namely PM10, PM2,5, and PM1. Particulate matter 10 (PM10) is a particle measuring 2.5-10 μm (micrometer), PM2.5 is also called fine particulate and has a diameter of 0.1-2.5 μm, and PM1 is also called ultrafine particle with a diameter ≤ 0.1 μm. Particulate Matter 10 (PM10) enters the body through the airway and then penetrates the proximal airway. Particulates Matter 2.5 (PM2,5) can inhale deeper than PM10, PM2.5, and then penetrate the lower airway to the lung parenchyma. Matter 1 particulate matter (PM1) can be inhaled up to the alveoli, alveolar epithelial cells, and blood vessels. [21.22]

Particulate Matter (PM) 10 is a particle in air that has a size of fewer than 10 micrometers and can enter the respiratory system. Cohort studies in the United States found that PM10 has a significant effect on the occurrence of lung cancer in men who don't smoke. An increase in PM10 levels can increase the risk of asthma and lung disease, including lung cancer. [23] Ozone (O3) is an important pollutant to know because ozone has strong oxidizing properties. Ozone is the result of a chemical reaction from nitrogen oxides and volatile organic compounds. The chemical reaction of ozone formation requires the presence of solar radiation (Ultra Violet (UV)) and high temperatures. [23,24] Ozone exposure in the short term can cause health problems such as difficulty breathing, coughing, and wheezing. [25] Maximum ozone exposure is 0.08 ppm (part per million) on average in eight hours of measurement. Ozone that exceeds ambient air quality standards will increase the risk of inflammation and damage to the human respiratory system. Ozone can cause ozonation and peroxidation in cells in the lungs. [26] Ozone is a pollutant associated with asthma events that occur indoors and is a risk factor for asthma attacks due to ambient air pollution. [27]

Nitrogen oxides found in the atmosphere are nitrogen oxides (NO), nitrogen dioxide (NO2) and nitrous oxide (N2O). The main source of nitrogen oxides is the result of the combustion process. The combustion process produces a lot of nitrogen and oxygen, which then reacts to nitrogen oxides. Motorized vehicles produce NO as much as 98 %. In the air, NO will change to NO2. Nitrogen dioxide is a toxic and dangerous gas for humans. Nitrogen oxide levels are dangerous if they exceed the ambient air quality standard. A high NOx can cause lung inflammation and result in death. [28] Exposure to NO2 can cause inflammation and changes in chronic and acute lung function and can increase allergic responses. [29] An increase in NO2 levels of 10 μg/m3 can increase the risk of asthma in adults. [30] The nature of nitrogen, which is toxic and can cause health problems makes nitrogen oxide as one indicator for air pollution. [31]

1. **Materials and Methods**

The study design was a retrospective quantitative longitudinal observational study, with the type of time stratified case-crossover research design. Sample selection using non-probability sampling-purposive sampling. The research data were processed statistically with the IBM SPSS 22 and Rstudio 1.2.1335 applications.

*2.1 Data on Asthma Patient Visits*

Asthma patient visit data (Code ICD-10 J45) obtain from five district health center located in Jakarta. Each Jakarta Administration City presented by one district health center. The selection of the district health center base on the nearest distance or less than five kilometers from the pollutant and weather measurement station of the Jakarta Provincial Environment Agency (DLH). Retrieval of data on visits of asthma patients with the permission of the Jakarta Health Office and the Health Department of Jakarta. The selected District health center consisted of District health center Cakung Subdistrict, East Jakarta, District health center Kebon Jeruk Sub-District, West Jakarta, District health center Kecamatan Kelapa Gading North Jakarta, District health center Kecamatan Pasar Minggu, South Jakarta, and District health center Senen, Central Jakarta. Exemption from research ethics was approved and issued by the Research Ethics Committee of Universitas Padjadjaran (Unpad) in Bandung under Document number 1219/UN6.KEP /EC/2018.

*2.2 Pollutant and Weather Data*

Jakarta's air and weather pollution data obtained from the rough data processing of the Urban Hybrid Models for Air Pollution Exposure Assessment (UDARA) research project and the Air Quality Laboratory of the Faculty of Environmental Engineering (Lab Air Quality TL), Bandung Institute of Technology (ITB). Crude data on pollutants processed by the UDARA and Lab Air Quality TL ITB study came from the pollutant measurement station owned by the Jakarta Provincial Environment Agency (DLH). Pollution data consisting of ozone, PM10, and NOx obtained from the Lab Air Quality TL ITB is the final data that has been processed and has followed the guidelines and guidelines from WHO. Ozone levels are a maximum measurement for 8 hours of analysis in μg/m3 units. PM and NOx levels were measured by a 24-hour average analysis, in of µg/m3.

*2.3 Statistical Analysis*

Univariate analysis of demographic data to see the amount of data by sex, age, and health center. Univariate analysis of pollutants and weather was carried out to determine the average value, maximum value, minimum value, standard deviation, interquartile range (IQR), mode, and 95% confidence interval (CI). Bivariate analysis was performed to see the correlation between pollutants, between weather, between pollutants and weather, between pollutants with asthma patient visits, and between weather and asthma patient visits. Correlation test uses the value of the Spearman analysis. The p-value indicates the presence or absence of correlation, and the amount of r shows the magnitude of the association. Positive sign or negative value of r indicates the direction of the association. Multivariate analysis was performed to see the relationship and effect (p) and odds ratio (OR) values. OR values ​​were calculated based on asthma, pollutant, weather, gender, and age patient visits. The multivariate analysis uses conditional logistic regression, with strata of the subject's identity.

Case and control criteria need for multivariate analysis of case-crossover designs. In the case-crossover study design, cases and controls were from the same patient. The case is the day of the visit of asthma patients in the event of an asthma attack. The first visit in 2017 was a case for asthma patients with repeated visits in 2017. Control is the day when an asthma patient is assumed to be healthy because he did not visit the health center. Control days are days 7 and 14 before and after the day of the case or the day of the visit of the asthma patient. Pollutant exposure is determined by the lag of day 1 to lag of day 3, namely the level of pollutants on the 3rd day to the 1st day before the pollutant measurement date.

1. **Results**

*3.1 Characteristics of Asthma Patients*

Jakarta asthma patients in this study are a combination of data from five sub-district health centers representing each one in each of the City Administration of Jakarta.

Table 1. Description of Jakarta Asthma Patients

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Description** | **Subjects** | | **2017** | **2018** |
| **n** | **%** | **n** | **n** |
| **Age**  0-5  ≥5-18  ≥18-65  ≥65 | 877  2384  7545  812 |  | 414  938  3116  306 | 463  1446  4429  506 |
| **Sex**  M  F | 5356  6262 |  | 2556  2218 | 3662  3182 |
| **Community Health Center**  Cakung  Kebon Jeruk  Kelapa Gading  Pasar Minggu  Senen | 2471  5134  1167  1413  1433 |  | 1289  2119  458  214  694 | 1182  3015  709  1199  739 |
|  |  |  |  |  |
|  |  |  |  |  |

Table 1. Number of Medical Record Data for Each Health Center in 2017

|  |  |
| --- | --- |
| District health center | Number of visits |
| Cakung | 1289 |
| Kebon Jeruk | 2119 |
| Kelapa Gading | 458 |
| Pasar Minggu | 214 |
| Senen | 694 |
| Total | 4774 |

Table 2. Description of Jakarta Asthma Patients

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Description | Asthma | | Man | | Women | |
| n | % | n | % | n | % |
| Age   1. 0 – 4 years 2. 5 – 14 years 3. 15 – 24 years 4. 25 – 34 years 5. 35 – 44 years 6. 45 – 54 years 7. 55 – 64 years 8. 65 – 74 years 9. > 75 years | 435  761  525  549  792  841  578  229  64 | 9,1  15,9  11,0  11,5  16,6  17,6  12,1  4,8  1,3 | 256  409  217  188  257  431  287  133  33 | 58,9  53,7  41,3  24,2  32,4  51,2  49,7  58,1  51,6 | 179  352  308  361  535  410  291  96  31 | 41,1  46,3  58,7  65,8  67,6  48,8  50,3  41,9  48,4 |
| Total |  |  | 2218 | 46,5 | 2556 | 53,5 |

The number of patient visits due to asthma with female sex is the patient with the highest number of visits. Female asthma patients are 7% more than the number of male patients. The difference is the same as the results of Basic Health Research (RISKESDAS) Ministry of Health Republic of Indonesia 2018, which states that nationally, there are more female asthma patients than men. [32] Based on the literature, women are more susceptible to asthma attacks because they have different anatomical forms of the lungs and respiratory system than men. Differences in lung size cause different ventilation functions and expiratory volume capacity. [33] Hormonal differences between women and men are another cause of the vulnerability of women affected by asthma attacks. [34]

In terms of age, the results of this study show that ages in the range of 5 to 14 years and 35 years to 54 years have the highest number of asthma visits. Ages 5 to 14 years are the age category of children. Children are vulnerable to health problems due to air pollution due to the immune system and the immature respiratory system, the respiratory rate of children is different from adults, the size of the airways in the respiratory system of children is smaller, the size of the lungs is small and not yet fully developed. [11,35]

In asthmatics aged 35 to 54 years, asthma attacks influenced by many factors. The age range of 35-45 years is the productive age range. At a productive age, asthma attacks can be caused by risk factors at work, such as exposure to allergens while working. [36] Behavior is one of the risk factors for asthma in adulthood. Smoking and consuming processed foods that contain preservatives and other additives are behaviors that can increase asthma attacks. Lack of movement and daily activity patterns are other behaviors that can be a risk of asthma attacks in adulthood. [37]

*3.2 Characteristics of Pollutants*

Pollutant data in this study is processed data carried out by UDARA and Lab Air Quality TL ITB. The rough data comes from the Jakarta Province AQMS DLH station. Data before processing are PM10, ozone, and NOx levels, the average measurement every 30 minutes. After being processed by the AIR research project and Lab. TL ITB Air Quality is a daily average data (24 hours) for PM10 and NOx, as well as a maximum measurement within 8 hours for ozone. The pollutant data processing is following WHO guidelines for pollutant parameters that have an impact on human health.

|  |  |
| --- | --- |
| (a) | (b) |
| (c) | (d) |

Graph 1. PM10 Levels (µg/m3) Average by Month In The Pollutant Measurement Station (a) Bundaran Hotel Indonesia Station, (b) Kelapa Gading Station, (c) Jagakarsa Station, and (d) Kebon Jeruk Station

Areas with high PM10 level measurements are in the Kebon Jeruk West Jakarta measurement station area. Kelapa Gading North Jakarta measurement station has a higher ozone value compared to 3 other regions. The most upper nitrogen oxide (NOx) is in the field of Kelapa Gading measurement station in North Jakarta. Pollutants that have levels above the annual ambient air quality standard determined by the Governor of Jakarta are ozone. The yearly average concentration of ozone at each measurement station has an above 30 µg/m3.

|  |  |
| --- | --- |
| (a) | (b) |
| (c) | (d) |

Graph 2. Ozone levels (µg/m3) Average by Month In The Pollutant Measurement Station (a) Bundaran HI Station, (b) Kelapa Gading Station, (c) Jagakarsa Station, and (d) Kebon Jeruk Station.

|  |  |
| --- | --- |
| (a) | (b) |
| (c) | (d) |

Graph 3. NOx Level (µg / m3) Average by Month In The Pollutant Measurement Station (a) Bundaran HI Station, (b) Kelapa Gading Station, (c) Jagakarsa Station, and (d) Kebon Jeruk Station

Table 3. Description of Pollutants in 2017

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Kebon Jeruk | | | Kelapa Gading | | | Jagakarsa | | | Bundaran HI | | |
|  | PM10 | O3 | NOx | PM10 | O3 | NOx | PM10 | O3 | NOx | PM10 | O3 | NOx |
| Average | 45,7 | 94,1 | 13,5 | 56,1 | 96,3 | 20,1 | 52,28 | 115,1 | 7,2 | 49,5 | 83,2 | 13,8 |
| Min | 3,2 | 21,4 | < 0,1 | 14,5 | 16,2 | < 0,1 | 4,0 | 35,8 | 0,8 | 5,9 | 12,5 | 3,6 |
| Max | 122,9 | 204,5 | 69,2 | 119,5 | 215,2 | 105,7 | 111,7 | 217,1 | 33,6 | 109,9 | 201,4 | 32,1 |
| Mode | 3,2 | 21,4 | 1,7 | 14,4 | 16,2 | < 0,1 | 4,0 | 35,8 | 0,9 | 5,9 | 12,5 | 3,6 |
| SD | 27,1 | 41,8 | 8,7 | 23,2 | 29,5 | 14,3 | 23,4 | 40,0 | 4,3 | 18,7 | 38,2 | 4,5 |

Note: PM10 and NOx = The average level of measurement 24 hours, Ozone (O3) = Maximum levels in 8 hours, min = Minimum value, max = maximum value, SD = Standard deviation, and IQR = Inter Quartile Range.

Table 3. Description of Pollutants in 2018

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Kebon Jeruk | | | Kelapa Gading | | | Jagakarsa | | | Bundaran HI | | |
|  | PM10 | O3 | NOx | PM10 | O3 | NOx | PM10 | O3 | NOx | PM10 | O3 | NOx |
| Average | 45,7 | 94,1 | 13,5 | 56,1 | 96,3 | 20,1 | 52,28 | 115,1 | 7,2 | 49,5 | 83,2 | 13,8 |
| Min | 3,2 | 21,4 | < 0,1 | 14,5 | 16,2 | < 0,1 | 4,0 | 35,8 | 0,8 | 5,9 | 12,5 | 3,6 |
| Max | 122,9 | 204,5 | 69,2 | 119,5 | 215,2 | 105,7 | 111,7 | 217,1 | 33,6 | 109,9 | 201,4 | 32,1 |
| Mode | 3,2 | 21,4 | 1,7 | 14,4 | 16,2 | < 0,1 | 4,0 | 35,8 | 0,9 | 5,9 | 12,5 | 3,6 |
| SD | 27,1 | 41,8 | 8,7 | 23,2 | 29,5 | 14,3 | 23,4 | 40,0 | 4,3 | 18,7 | 38,2 | 4,5 |

Note: PM10 and NOx = The average level of measurement 24 hours, Ozone (O3) = Maximum levels in 8 hours, min = Minimum value, max = maximum value, SD = Standard deviation, and IQR = Inter Quartile Range.

*3.3 Pollutants Exposure and Asthma Patient Visits*

3.3.1 Correlation of Pollutants and Weather

The first bivariate analysis in this study was conducted to see the relationship between pollutant and weather variables.

Table 4. Correlations between Pollutants and the Weather of Jakarta

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variabel | Value | PM10 | NOx | O3 | Temperature | Humidity | Rainfall |
| PM10 | r | 1,000 | -0,024 | 0,566 | 0,405 | -0,176 | -0,021 |
|  | *p value* | - | 0,296 | < 0,05 | < 0,05 | < 0,05 | 0,363 |
| NOx | r | - | 1,000 | -0,144 | -0,026 | 0,138 | -0,062 |
|  | *p value* | 0,0-55 | - | < 0,05 | 0,275 | < 0,05 | < 0,05 |
| O3 | r | - | 0,0-55 | 1,000 | 0,282 | -0,319 | 0,012 |
|  | *p value* | 0,0-55 | - | - | < 0,05 | < 0,05 | 0,600 |

r = correlation coefficient, p value = significance value (meaningfulness)

Table 4. shows the correlation between PM10 and ozone. The correlation value is p <0.05 with r of 0.566, meaning that PM10 is correlated moderately with ozone. These results are the same as those of Jalaluddin et al. research in Sydney, which stated that there was a moderate correlation (r = 0.31 - 0.53) between ozone and particulates in the air. [38] Ozone and NOx correlate with p values ​​<0.05 and r = -0.144 means that the correlation is negative. The negative correlation because NOx is a precursor in the formation of ozone in the air. [39.40]

Ozone and PM10 correlate with temperature and humidity. Heat and ozone are positively correlated, while ozone and moisture are negatively correlated. Thickness and PM10 are negatively correlated, temperature, and PM10 are positively correlated. Nitrous oxide (NOx) correlates with humidity and rainfall. The correlation between NOx and humidity is directed positively, while the rain is negatively correlated.

Tresnasari et al. Research (2018) state that there is an explanation for the correlation between pollutants and weather. Increased temperature, decreased humidity, and rainfall causes the air to become dry. PM10 is easily lifted and floats in free air, so it is easily exposed and will increase PM10 levels in the air. Increased air temperature or decreased humidity and rainfall cause relatively stable atmospheric conditions. The stability of the atmosphere causes the inversion layer can not rise, and the height of the mixing layer is low. Ozone will be trapped and experience air mass mixing with a smaller volume. Low humidity and rainfall cause dry air conditions HNO3 not forme, and NOx remains high. [41]

3.3.2 Relationship of Pollutants With Patient Visits Due to Asthma

A second bivariate analysis was conducted looking at the correlation between the number of asthma patient visits, pollutant, and weather.

Table 5. Correlations Between Pollutants, Weather and Asthma Patients Visit of Jakarta

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Value | PM10 | NOx | O3 | Temperature | Humidity | Rainfall |
| Asthma Patients Visit | r | -0,022 | 0,178 | -0,025 | 0,074 | 0,029 | -0,058 |
| *p value* | 0,380 | < 0,05 | 0,288 | < 0,05 | 0,238 | 0,014 |

r = correlation coefficient, p value = significance value (meaningfulness)

There is a correlation between pollutants and asthma patient visits in Jakarta. Correlated pollutants are NOx with p values ​​<0.05 and r = 0.178. A value of r close to 1 means that the correlation is positive. Increased levels of NOx can result in increased patient visits due to asthma attacks to the district health center. The results of a meta-analysis conducted by Khreis et al. (2017) found that if there was an increase in NO2 content of 4 μg/m3 or an increase in NOx 30 μg/m3 could be a risk of asthma. [42]

The temperature and visit of asthma patients correlate with p <0.05, but the strength of the association is a weak value of r = 0.074. Indonesia is a tropical country and has two seasons, the dry season and the rainy season. In the rainy season there can be a decrease in temperature. Cold temperatures can trigger asthma in children and can increase the severity of asthma in adulthood. [43] The value of r is close to zero, meaning that the correlation is tiny; this can occur because cold temperatures are a nonspecific factor for an asthma attack. Cold temperatures can increase allergic responses, cause allergic rhinitis, and cause the formation of mucus in the airways that will develop into asthma. [43.44]

Multivariate analysis was performed to see the relationship and the magnitude of the risk of pollutants on patient visits due to asthma. The relationship between pollutants and patient visits due to asthma see from the significance value (p <0.05). The odds ratio (OR) calculation is done to determine the magnitude of the risk of pollutants as a trigger for an asthma attack, OR calculation using Rstudio 1.2.1335 application with survival package (conditional logistic regression). The case is the day of the patient's visit to the health center with asthma complaints. Controls were patients with asthma cases on the 7th and 14th days before and after an asthma attack. Control day is the same day as the case. The lag day is pollutant exposure the day before case day and control day.

Table 6. Relationship of Pollutants and Weather With Patient Visits Due to Asthma Attacks in Jakarta

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Pollutant | Lag day | OR | 95 % CI | *p*-value |
| PM10 | 1  2  3 | 0,9996  0,9976  0,9990 | 0,9963 – 1,003  0,9940 – 1,001  0,9957 – 1,002 | 0,81  0,17  0,52 |
| O3 | 1  2  3 | 1,0013  1,0003  1,0016 | 0,9998 – 1,003  0,9987 – 1,002  1,0001 – 1,003 | 0,09  0,72  0,04\* |
| NOx | 1  2  3 | 1,0050  0,9959  1,0027 | 1,0003 – 1,010  0,9907 – 1,001  0,9979 – 1,007 | 0,04\*  0,12  0,27 |

\* = significant value <0.05. This model already controls the correlation between weather and pollutants.

1. **Discussion**

Multivariate analysis results for Jakarta data obtained the results of pollutants that have a relationship and influence with patient visits because asthma to the district health center is ozone and NOx. Ozone exposure on the 3rd day lag with p = 0.04 with OR 1.0016 (95% CI 1,0001-1.003). Lag day 1 of NOx exposure with p = 0.04 and OR of 1.0050 (95% CI 1,0003-1.010). Ozone and NOx exposure can cause an increase in the number of asthma patient visits in Jakarta. Ozone can cause asthma attacks and increase asthma patient visits three days after ozone exposure. Exposure to NOx can cause asthma attacks and increase patient asthma visits one day after exposure. The conclusion that ozone and NOx are environmental components that can be risk factors for asthma

The relationship between ozone and asthma patient visits can occur due to high ozone levels in Jakarta. Seen from the average annual ozone level of Jakarta, it is above the maximum limit required for ambient air quality standards set by the Governor of Jakarta Province. Ozone is a powerful oxidizer that is very dangerous for biological tissues, especially lung tissue. [45] Exposure to high levels of ozone or continuous ozone exposure can trigger asthma attacks. Some studies have found that ozone can have acute and chronic effects on asthma. Asthma caused by ozone can occur due to exposure to small levels in a long time or high levels in a short time. [46] In this study, there was an interval from ozone exposure to asthma attacks; this shows the chronic effects of ozone.

NOx levels are below ambient air quality standards but have a relationship with asthma patient visits in Jakarta. The NOx group consists of NO, NO2, and N2O. In this research, NOx component analysis was not carried out. Each component of nitrogen oxide has a different level of toxicity. NO2 has a toxicity level 4 times greater than NO. NOx levels which are below the ambient air quality standard may contain NO2 compounds. [47.48] Research Jalaludin et al. (2008) and Szyszkowicz et al. (2018) found that short-term exposure by pollutants with low levels or below the ambient air quality standard still has a relationship with an increase in visits of respiratory disease patients including asthma. [38.49]

In this study, there was no relationship between PM10 and asthma patient visits in Jakarta. The absence of an association between PM10 can explain by an approach to health risk factor analysis consisting of exposure, vulnerability, and source of exposure. [50] The source of exposure in this study is PM10. The measured PM10 level is below the ambient air quality standard determined by the Government of Jakarta. Small amounts of PM10 cannot cause inflammation of the respiratory system and cause asthma attacks. The potential of PM10 in causing health problems depends on the deposition of PM10 in the airways, composition, and surface components. [51]

Asthma is an allergic disease of the lungs due to the accumulation of mucus due to inflammation. The occurrence of asthma must be preceded by contact between PM10 as an allergen and immune cells as a recipient of an allergic response. If the exposure of PM10 as an allergen is too small and the presence of PM10 is recognized not as a foreign substance or allergen then inflammation, and oxidative stress as the beginning of an asthma attack does not occur. [52]

The PM10 in causing asthma determined by its effective dose. The effective dose of PM10 in each place will be different because influenced by the types and components of PM10. Heavy metals such as lead (Pb) and sulfate compounds can increase the effective dose of PM10. Further research is needed to determine the effective dose of PM10 and other pollutants in the Jakarta area. [52,53]

The strength of PM10 in causing asthma attacks influenced by the composition of substances, types of substances, and the number of substances contained in PM10. The PM10 component consists mainly of carbon, organic compounds, and metals. The composition of PM10 varies greatly, depending on the source of the pollutant that produces PM10, meteorological conditions (such as temperature, rainfall, and wind speed), as well as industrial activities and traffic densities in the area. [54] In this study the measured PM10 is the average number of PM10 particles measured 24 hours. Analysis of the composition of PM10 not was carried out so that it could not see the cause of the absence of an association between PM10 and asthma patient visits. The presence of heavy metals such as iron and copper in PM10 can cause airway inflammation and asthma attacks. [55.56]

The vulnerability of individuals affected health disorders influenced by individual internal factors such as metabolism, the immune system, and others, external factors such as economic factors, social factors, socio-demographic, natural and environmental factors, and other external factors. (50) Economic factors can we see from the kind of work and how much income every month. Environmental factors can be in the form of residential area information. In this study no data was collected related to information on external factors that could make individuals vulnerable to asthma attacks. The limitation of patient information becomes an obstacle in determining the level of individual vulnerability to PM10 exposure.

PM10 exposure to individuals greatly influences the incidence of asthma attacks. Research conducted by Nurmala and Suhartono (2018) found that levels of Suspended Particulate Matter (SPM) with a size of 1-100 microns have no relationship or correlation with asthma attacks. The absence of this relationship causes the number of sources of exposure that are too small, short exposure time, and the size of SPM that is too large to enter deeper into the respiratory tract. [57] The results of Nurmala and Suhartono's research are in line with the results of Abe et al. (2009) in Japan, which states that there is no relationship between SPM and asthma. [58] Exposure to PM10 with levels below ambient air quality standards cannot cause asthma attacks.

Exposure to PM with a size of less than 2.5 is more at risk of causing asthma attacks compared with PM10. Further research is recommended to measure PM2.5 levels to see the relationship with asthma patient visits. This difference in risk is due to the smaller size of PM2.5, larger surface, absorption as a larger allergen, and PM2.5 levels in the air which is more stable in the atmosphere, and the ability of PM2.5 is more significant in causing inflammation in the channel Respiratory. [9]

1. **Conclusions**

In this study, the results show that there is a relationship between ozone and NOx exposure to asthma patient visits in Jakarta. Asthma attacks are expected to occur three days after ozone exposure and one day after NOx exposure. PM10 pollutants in this study did not show any relationship with asthma patient visits.

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