E3S Web of Conferences **495**, 03007 (2024) https://doi.org/10.1051/e3sconf/202449503007
ICYES 2023

Ambient air pollution and visit of asthma patients: case study in DKI Jakarta 2017

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Abstract. Asthma is a worldwide disease that affects all races, ages, and genders. In 2017, asthma attacked 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, O_3, and NOx) in DKI Jakarta in 2017. The results from this study: 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 DKI Jakarta. It can be concluded that ozone and NOx are associated with asthma patient visits in DKI Jakarta, and this study on PM10 pollutants did not show any relationship with patient visits due to Asthma in DKI Jakarta.

1 Introduction

Air pollution represents a significant and pressing hazard, ranking among the leading causes of mortality today. According to the World Health Organization (WHO) 2015 figures, air pollution accounted for 6.4 million fatalities globally, with approximately 4.2 million deaths attributed to ambient air pollution. [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 significant cause of the worldwide 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). In 2015, in Indonesia, the number of deaths caused by air pollutants was 78,600 (95% UI 62,000-92,700), with a disease burden of 1.08 million DALYs (95% UI 884,000-1,322,700). [5,6]

According to the DALYs theory, each person has a certain amount of years to live if they are in optimal health at birth. Individuals may lose these years of healthy life by passing away before a reference life expectancy, dealing with illness, or both. The DALY metric precisely measures these losses in years of healthy life. Thus, diseases with a more significant impact on public health will be responsible for more DALYs in the population than those with a lower impact. [7,8]

DALY = (Number of cases x duration till remission or death x disability weight) + (Number of deaths x life expectancy at the age of death) [7] (1)

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 at risk of lung cancer, asthma, chronic obstructive pulmonary disease, ischemic heart disease, and stroke. [9] Epidemiological studies show 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. [10,11] 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 the most significant cause of asthma epidemics, especially exposure to traffic-related air pollution. [12,13] The Global Initiative on Asthma (GINA) reports that 2017 asthma attacks affected around 300 million people worldwide. Asthma attacks are more common in urban areas and are increasing in developing countries. [14,15]

Data in 2016 shows that as many as 92 % of the human population live in places with air quality that is not appropriate and exceeds the limits or air quality standards issued by WHO. [16-18] The World Health Organization (WHO) determines several types of pollutants as indicators of air quality, including ozone (O_3), Particulate Matter (PM), and NOx. [18]. Composition Particulate matter (PM) is a mixture of solid and liquid particles from various sources. Particulate matter (PM) is divided into three based on its diameter size: 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 penetrates the proximal airway. Particulates Matter 2.5 (PM2,5) can be inhaled deeper than PM10 PM2.5 and then penetrate the lower airway to the lung parenchyma. Matter 1 particulate matter (PM1) can be inhaled into the alveoli, alveolar epithelial cells, and blood vessels. [19,20].

Ozone (O_3) is a critical pollutant because ozone has oxidizing solid properties. Ozone results from 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. [21] In the short term, ozone exposure can cause problems such as difficulty breathing, coughing, and wheezing. [22] Ozone is a pollutant associated with indoor asthma events and is a risk factor for asthma attacks due to ambient air pollution. [23]

Nitrogen oxides found in the atmosphere are nitrogen oxides (NO), nitrogen dioxide (NO_2), and nitrous oxide (N_2O). The primary 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 make NO as much as 98 %. In the air, NO will change to NO_2. Nitrogen dioxide is a toxic and dangerous gas for humans. Nitrogen oxide levels are hazardous if they exceed the ambient air quality standard. A high NOx can cause lung inflammation and result in death. [24] Exposure to NO_2 can cause inflammation, changes in chronic and acute lung function, and increase allergic responses. [25] An increase in NO_2 levels of 10 µg/m^3 can increase the risk of asthma in adults. [26] The nature of nitrogen, which is toxic and can cause health problems, makes nitrogen oxide one indicator of air pollution. [27] The objective of this study was to investigate the connection between air pollution and the occurrence of asthma attacks.

A large city like Jakarta is one of the main sources of air pollution and greenhouse gas emissions. In 2016, the population of Jakarta was 10.3 million. The Indonesia Statistical Agency (2017) reports that there were 18.7 million motor vehicles in Jakarta in 2016—including trucks, buses, passenger cars, cargo automobiles, and motorcycles. According to the IQAir monitoring website, Jakarta's air quality index (AQI) is consistently in the red and orange categories, indicating unhealthy and unhealthy air conditions for sensitive groups. [28, 29]

2 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.

Asthma patient visits data (Code ICD-10 J45) was obtained from five district health centers in DKI Jakarta. Each DKI Jakarta Administration City is presented by one district health center. The district health center selection is based on the nearest distance or less than five kilometers from the pollutant and weather measurement station of the DKI Jakarta Provincial Environment Agency (DLH). Retrieval of data on asthma patient visits 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. The Research Ethics Committee of Universitas Padjadjaran (Unpad) in Bandung approved and issued an exemption from research ethics under Document number 1219/UN6.KEP /EC/2018.

Jakarta's air pollution data was 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 DKI 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/m^3 units. A 24-hour average study of rg/m3 measured PM and NOx levels.

Case and control criteria are needed 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 asthma patient's visit. 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.

3 Results and Discussion

Since the 1990s, the disability-adjusted life year (DALY) has been extensively utilized to assess the disease burden worldwide and in different regions. Since many environmental contaminants pose a risk to human health, the disability-adjusted life year (DALY) is a recognized indicator for estimating the impact of environmental pollution on health to disease burden. Regarding environmental contaminants that risk human health, health effect/risk evaluation is essential for converting pollution data into illness data through exposure and dose-response analyses, which need meticulous model design and parameter specification. Pollutants originating from air pollution at specific doses can cause certain diseases. This disease can cause death and affect birth, as included in the DALY calculation. [30] Asthma is one of the Chronic respiratory diseases with DALY 22 800 (18 100 to 28 300) in 2017. [31]

Economic growth is affected by air pollution. Charges are required to manage pollution and prevent it from endangering human health. When humans become ill due to exposure to pollution, they must pay for medical care. Medical expenses will have an impact on income and purchasing power. [31, 32] The annual cost of the health effects of air pollution was estimated to be USD 2943.42 million, or 2.2% of the GDRP for the Province of Jakarta. [33]

Table 1 describes ambient air pollution data, consisting of 3 pollutants: PM 10, ozone, and NOx in Jakarta in 2017.

Table 1. Description of Pollutants in 2017

Variable	Kebon Jeruk			Kelapa Gading			Jagakarsa			Bundaran HI		
	PM10	O_3	NOx	PM10	O_3	NOx	PM10	O_3	NOx	PM10	O_3	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 within 24 hours, Ozone (O_3) = Maximum levels in 8 hours, min = Minimum value, max = maximum value, SD = Standard deviation, and IQR = Inter Quartile Range.

Table 2. Relationship of Pollutants With Patient Visits Due to Asthma Attacks in DKI Jakarta

Pollutant	Lag day	OR	95 % CI	*p*-value
PM10	1	0,9996	0,9963 – 1,003	0,81
	2	0,9976	0,9940 – 1,001	0,17
	3	0,9990	0,9957 – 1,002	0,52
O_3	1	1,0013	0,9998 – 1,003	0,09
	2	1,0003	0,9987 – 1,002	0,72
	3	1,0016	1,0001 – 1,003	0,04*
NOx	1	1,0050	1,0003 – 1,010	0,04*
	2	0,9959	0,9907 – 1,001	0,12
	3	1,0027	0,9979 – 1,007	0,27

Table 2 shows a correlation between pollutants and asthma patient visits in DKI Jakarta. Correlated pollutants are NOx and ozone with p values < 0.05. Increased levels of NOx can result in improved patient visits to the district health center due to asthma attacks. A meta-analysis by Khreis et al. (2017) found that an increase in NO_2 content of 4 $\mu g/m^3$ or an increase in NOx 30 $\mu g/m^3$ could be a risk of asthma. [27]

The correlation between ozone and asthma patient visits in DKI Jakarta is attributed to elevated ozone levels. The annual average ozone concentration in DKI Jakarta exceeds the maximum threshold stipulated by the Governor of DKI Jakarta Province for ambient air quality standards. Ozone, a potent oxidizing agent, poses a significant hazard to biological tissues, particularly lung tissue. [34] Exposure to high ozone levels 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 negligible levels in a long time or high levels in a short time. [35] In this study, there was an interval from ozone exposure to asthma attacks; this shows the chronic effects of ozone.

In DKI Jakarta, NOx levels, despite falling below the established ambient air quality standards, are associated with asthma patient visits. The NOx group encompasses NO, NO2, and N2O. However, this study did not analyze the individual components of NOx. It's worth noting that each element within the nitrogen oxide group carries varying toxicity levels. Specifically, NO2 exhibits a toxicity level four times higher than that of NO. Therefore, it is possible that even when NOx levels are within the acceptable air quality standard, they may contain NO2 compounds, contributing to the observed asthma-related issues. [36,37] Research by Szyszkowicz et al. (2018) found that short-term exposure to pollutants with low levels or below the ambient air quality standard still has a relationship with increased visits of respiratory disease patients, including asthma. [38]

In this study, there was no relationship between PM10 and asthma patient visits in DKI Jakarta. The absence of an association between PM10 can be explained by an approach to health risk factor analysis consisting of exposure, vulnerability, and source of direction. [39] 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 DKI Jakarta. Small amounts of PM10 cannot cause inflammation of the respiratory system and cause asthma attacks. The potential of PM10 to cause health problems depends on the deposition of PM10 in the airways, composition, and surface components. [40]

The potential of PM10 to trigger asthma attacks is determined by its composition, the significance of the components, and the quantity of substances within PM10. PM10 is primarily composed of carbon, organic compounds, and metals. The composition of PM10 varies wildly, depending on the source of the pollutant that produces PM10, meteorological conditions (such as temperature, rainfall, and wind speed), industrial activities, and traffic densities in the area. [41] The study measured the average concentration of PM10 particles over a 24-hour. Nevertheless, an analysis of PM10's composition was omitted, which hinders the ability to elucidate the factors contributing to the absence of a link between PM10 and asthma patient visits. It's crucial to underscore that the existence of heavy metals such as iron and copper in PM10 particles has the potential to induce airway inflammation and provoke asthma attacks. [42,43]

The vulnerability of individuals affected by health disorders can be influenced by individual internal factors such as metabolism, the immune system, and others, as well as external factors such as economic factors, social factors, socio-demographic, natural and environmental factors, and others. (44) Economic factors, as reflected in employment and income, and environmental factors, such as details concerning residential areas, were not included in the data collection for this study. The absence of information regarding external factors that might render individuals susceptible to asthma attacks presents a challenge. The limited availability of patient data is a barrier to assessing individual vulnerability to PM10 exposure.

Internal factors are risks that originate from the human body itself. Internal factors are related to the individual's anatomical morphology and metabolism. Internal factors in most people with asthma are atopic, and their airways, from the trachea to the peripheral airways, are inflamed in an allergic pattern. Often called Type 2 (T2) asthma, allergic inflammation is fueled by CD4+ T-helper 2 (Th2) cells, which release IL-4, IL-5, and IL-13. Although vascular congestion and airway edema from leaky bronchial arteries may also be factors, the contraction of airway smooth muscle is the primary cause of airway narrowing in asthma. The defining physiological abnormality of asthma, airway hyperresponsiveness (AHR), is caused by inflammation in the airways of asthmatic patients. AHR accounts for airway narrowing in response to environmental triggers and produces the characteristic variable asthma symptoms, such as nocturnal worsening. Although the exact mechanisms underlying AHR are unknown, they most likely have to do with increased mediator release from inflammatory cells, especially mast cells, increased smooth muscle contractility, increased sensitivity of airway sensory nerves, and preexisting geometric airway narrowing. Asthmatic airways are characterized by eosinophilic inflammation. In asthma, structural cells of the airways, such as fibroblasts, endothelium, epithelial, and smooth muscle cells, are significant producers of inflammatory mediators such as cytokines and lipid mediators. [45]

External factors come from outside the human body. Allergens can come from the environment where humans live. Allergens enter the respiratory system and make inflammatory airways. Exposure to allergens found inside the home, such as cockroaches, mice, fungus, dust mites, and pets (particularly cats and dogs). Compared to childhood-onset asthma, there is less evidence linking traffic-related air pollution to adult-onset asthma. Occupational contact with grains, dust, or other allergens has been detrimental to asthma. Asthma is currently the most common respiratory illness associated with the workplace, and precautions have been taken for some occupational exposures shown during the past 40 years. Recent research has examined the impact of lifestyle and nutrition. [46]

Exposure to PM10 plays a significant role in the occurrence of asthma attacks in individuals. A study by Nurmala and Suhartono 2018 revealed that Suspended Particulate Matter (SPM) levels ranging from 1-100 microns showed no association or correlation with asthma attacks. The lack of this connection can be attributed to the limited sources of exposure, brief exposure periods, and the relatively large size of SPM particles, which hinder their penetration into the deeper regions of the respiratory tract. [44] Asthma attacks are not caused by exposure to PM10 levels lower than the established ambient air quality standards.

Another respiratory disease correlated with pollution is COPD. Respiratory risk has been linked to brief exposure to key air pollutants, including O3, CO, NO2, SO2, PM10, and PM2.5. There is currently little information available on the likelihood of exacerbations of chronic obstructive pulmonary disease (COPD). The current study aimed to assess the relationships between the risk of COPD exacerbations and brief exposure to major air contaminants. There were 59 studies in total. Except for CO (100 μg/m3), the risks of COPD were computed for every 10 μg/m3 increase in pollutant concentrations in the single-pollutant model. For both gaseous and particle contaminants, a significant correlation was found between short-term exposure and the probability of COPD exacerbation. The largest correlations were seen at lag0 and lag3 for gaseous and particle air pollution, respectively. In addition to providing additional evidence of the overall negative effects, the subgroup analysis decreased the heterogeneities. PAFs varied from 0.60% to 4.31% depending on the pollutants when 100% exposure was assumed. In low- and middle-income nations compared to high-income nations, the detrimental health impacts of SO2 and NO2 exposure were more pronounced: SO2, relative risk: 1.012 (95% confidence interval: 1.001, 1.023); NO2, relative risk: 1.019 (95% confidence interval: 1.014, 1.024). [47]

Exposure to delicate particulate matter (PM) particles smaller than 2.5 microns poses a higher risk of triggering asthma attacks compared to PM10. It is advisable to conduct further research to investigate the correlation between PM2.5 levels and asthma patient visits. This difference in risk can be attributed to the smaller size of PM2.5 particles, their larger surface area, their capacity to act as more substantial allergens, their increased atmospheric stability, and their more significant potential to induce inflammation in the respiratory system. [11, 48]

For the next research, we need to know about the composition of PM2.5. PM2.5 may contain an ion, heavy metal, or organic allergen; if we know the composition, we can forecast the interaction between PM2.5 and cells in the human body, especially the respiratory system cells. [48]

Conclusions

This study shows a relationship between ozone and NOx exposure to asthma patient visits in DKI Jakarta. Asthma attacks are expected three days after ozone exposure and one day after NOx exposure. PM10 pollutants in this study did not correlate with asthma patient visits.

The authors are grateful to the National Research and Innovation Agency (BRIN), Universitas Padjadjaran (Unpad), and thanks to Indah Kusmartini from the Research Center for Radiation Detection and Nuclear Analysis Technology – BRIN.

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