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SO_2 Concentration and the Occurrence of Acute Respiratory Infection in Children Under Five

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Abstract

Jakarta is the capital city of Indonesia, with 10.7 million inhabitants with poor air quality as of 2020. Higher levels of pollution often come with an increase in the number of health risks and pneumonia cases. This study aimed to determine the association between SO_2 concentration and the occurrence of acute respiratory infection (ARI) in children under five. An ecological time series design was implemented during the study by utilizing secondary data of SO_2 concentrations and ARI from the Indonesian Agency for Meteorological, Climatological, and Geophysics, the Special Capital Region of Jakarta Environmental, and Health Office. Statistical correlation tests were performed to analyze the association between SO_2 concentration and ARI prevalence in five municipalities cities in Jakarta from 2018-2021 based on the rainy and dry seasons. The average concentration of SO_2 was 18.06–20.89 μg/m^3. The SO_2 concentration and the occurrence of ARI in children under five in Jakarta from 2018 to 2021 showed a weak relationship (r = 0.24). It seems that children under five in Jakarta spent their time indoors rather than outdoors; therefore, they were exposed to fewer transportation emissions.

Keywords: acute respiratory infection, air pollution, children under five, SO_2 concentration

Introduction

Acute respiratory infection (ARI) is a major cause of morbidity and mortality from infectious diseases worldwide. The mortality rate due to ARI has reached 4.2 million annually worldwide, 98% of which are caused by respiratory infections.[1] High mortality rates due to ARI have been observed in infants, children, and the elderly, especially in countries with low and middle incomes per capita.[2] The World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF) call ARI or pneumonia "the forgotten killer of children" or a forgotten pandemic because of the large number of deaths from ARI.[3]

The 2017 Indonesian Demographic and Health Survey (IDHS) stated that the child mortality rate was 32 per 1,000 live births.[4] Pneumonia was the second most common cause of death after diarrhea in 2019, with 314 (10.7%) deaths from 2,927 deaths occurring between 12–59 months.[5] Data from the Directorate General of Disease Prevention and Control Services, Ministry of Health of the Republic of Indonesia, in 2020, showed an increment in the coverage of toddler pneumonia cases throughout Indonesia from 51.2% in 2017 to 56.5% in 2018 and 52.9% in 2019.[5] The death rate from pneumonia in the infant group was almost twice for a group of children aged 1–4 years.[5]

Based on the 2019 Health Profile reported by the Special Capital Region of Jakarta Health Office, the observation of morbidity from year to year showed an increment in the percentage of pneumonia cases in Jakarta, as many as 45.301 cases or 121.9% compared to the 2018 report which was 217.5% of the total 14,629 cases.[6] Air pollution can be caused by humans or occur naturally in the environment.[7] Other factors at risk of increasing the occurrence of ARI in children under five are environmental conditions (such as air pollution, the density of household members, cleanliness, humidity, temperature, and season) and the availability and effectiveness of public health services.[2]

Jakarta's air pollution is caused by several factors, such as air pollutant emissions. The pollutant emissions degrade air quality in Jakarta.[8] Air pollution in Jakarta is increasing from year to year. As a developing city, Jakarta produces more and more air pollution, which causes air quality degradation because of population activities, industrial activities, and transportation. One factor that

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causes ARI increment is the high levels of ambient air sulfur dioxide (SO_2) and particulates (PM_{10}) concentrations. The Special Capital Region of Jakarta Environmental Office monitors the levels of primary pollutants, such as nitrogen dioxide (NO_2), SO_2, ozone (O_3), carbon monoxide (CO), and PM_{10} with the Air Quality Monitoring System (AQMS) in five municipalities cities in the Special Capital Region of Jakarta.[5] It is estimated that there were more than 5.5 million air pollution-related disease cases in Jakarta in 2010, including 2.45 million cases of ARI.[9]

A previous study has discussed that ambient air pollutants have an essential role in contributing to the high respiratory infection ratio by making people more vulnerable to the virus.[10] The WHO also reported that seven million die annually because of fine particles in the polluted air.[8] Two previous studies recognized that environmental temperature significantly impacts the prevalence of childhood respiratory diseases.[11,12] In contrast to exposure to moderate and comfortable temperatures, exposure to extreme hot and cold weather is associated with increased ARI morbidity. Therefore, current evidence suggests that ARI increases in temperate climates during the colder months of the year.[13] Indonesia's tropical climate is divided into two seasons in one year: the rainy and dry seasons. As a tropical country, there is a change of seasons every six months.[13] This study aimed to determine the association between SO_2 concentrations and the occurrence of ARI in children under five in Jakarta in 2018-2021.

Method

This study used an ecological design with aggregated data by time to assess the association between monthly numerical data in both SO_2 concentrations and the occurrence of ARI in children under five. This study was conducted in five municipalities cities (Central, North, West, South, and East Jakarta) of the Special Capital Region of Jakarta Province. The study population consisted of children under five in Jakarta who had ARI during the study period. The data used were from January 2018 to March 2021 and grouped into rainy and dry seasons. The monthly average SO_2 data for Jakarta for January 2018-March 2021 were accessed online through the Special Capital Region of Jakarta Environmental Office website (*https://lingkunganhidup.jakarta.go.id/publikasi/laporanudara*). These data were based on daily measurements from January 2018 to March 2021 from five AQMS in the Special Capital Region of Jakarta. Statistical correlation tests were performed to analyze the association between SO_2 concentration and ARI prevalence in five municipalities cities of the Special Capital Region of Jakarta over the last four years based on the rainy and dry seasons.

Results

The ARI variable had a minimum value of 708 cases, a maximum value of 6,347 cases, and a median value of 3,133 cases. The ARI variable had a standard deviation (SD) of 1,624, a mean of 2,948, and a 95% confidence interval (CI) of 2,422–3,475, indicating that 95% believe that the number of ARI cases was 2,948 in the range of 2,422–3,475 cases. The normality test results using the Kolmogorov-Smirnov test showed a p-value of 0.145 (>0.05), indicating that the ARI data were normal. Furthermore, the distribution was skewed to the right (positive skewed) based on the skewness value of +0.136 (Table 1).

The SO_2 concentration variable had a minimum value of 13.22 g/m^3, a maximum value of 31.46 g/m^3, and a median value of 19.31 g/m^3. The SO_2 concentration variable had an SD of 4.37, a mean SO_2 concentration of 19.31, and a 95% CI of 18.06–20.89). The normality test results using the Kolmogorov–Smirnov test showed a p-value of 0.259 (> 0.05), indicating that the SO_2 concentration data were normal. The distribution was skewed to the right (positive sloping) based on the skewness value of +1,154 (Table 1).

The number of ARI cases of children under five included in this study was between 708 and 6,347 occurrences (mean = 2,948, SD = 1,624). The data were normally distributed (Kolmogorov–Smirnov normality test with a p-value of 0.145; the distribution was skewed to the right). The mean SO_2 concentration was 19.31 g/m^3 (18.06–20.89 g/m^3, SD = 4.37). The results of the normality test using the Kolmogorov–Smirnov test showed a p-value of 0.259 (>0.05), which indicated that the SO_2 concentration data were normal, with a distribution

Table 1. Distribution of Acute Respiratory Infection in Children under Five and SO_2 Concentration in the Special Capital Region of Jakarta in 2018-2021

Variable	n	Min-Max	Mean	Median	SD	95% CI	p-value*	Skewness
ARI in children	39	708–6,347	2,948	3,133	1,624	2,422–3,475	0.145	0.136
SO_2 concentration	39	13.2–31.5	19.48	19.31	4.37	18.06–20.89	0.259	1.154

Notes: SO_2 = Sulfur Dioxide, SD = Standard Deviation, CI = Confidence Interval, ARI = Acute Respiratory Infection
*Test for normality with a one-sample Kolmogorov–Smirnov test

skewed to the right (+1.154) (Table 1).

The number of ARI cases of children under five during January 2018-March 2021 showed a fluctuating trend, with some periods showing a significantly high number of cases, namely: February 2018 (almost 5,000 cases), February 2019 (> 6,000 cases), and March 2020 (> 6,000 cases). In the other months, the number of cases was approximately 2,000–4,000 and sharply decreased to approximately 1,000 in May 2020-March 2021 (Figure 1).

The SO_2 concentrations in the Special Capital Region of Jakarta from January 2018 to March 2021 showed a fluctuating trend, with some showing significantly high concentrations, especially in January 2018, December 2020, February 2021, and March 2021 (Figure 2). The SO_2 concentrations in the Special Capital Region of Jakarta in 2018-2021 were higher during the months of November and December 2020 and January, February, and March 2022 and tended to decrease from April to October. This pattern showed that higher SO_2 concentrations occurred more frequent in the rainy season (Figure 3).

Analysis of the relationship between SO_2 concentration and the incidence of ARI in infants using the Spearman's correlation test between SO_2 concentrations and the incidence of ARI in children under five in the Special Capital Region of Jakarta in 2018-2021 showed a significant relationship (r = 0.241; p-value = 0.139) at a 1-month lag (Table 2). The relationship was negative, indicating that an increase in one variable was not followed by an increase in another. It means that if there is an increase in the monthly SO_2 concentration, it will not be followed by an increase in the number of ARI occurrences monthly in children under five in the following month (Figure 4).

The ARI's occurrence related to exposure to air pollution might have a delay of up to 14 days due to the variation of incubation periods, especially among children under five. Therefore, this study analyzed the association between SO_2 concentration and the number of ARI cases using the lag = 1 month data for the ARI cases, given that it might explain the association between SO_2 concentration and the occurrence of ARI cases in children under five more accurately. Furthermore, to provide

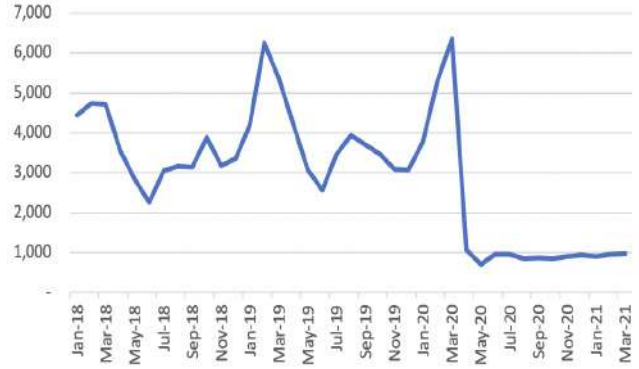

Figure 1. Monthly Cases of ARI in Children Under Five in the Special Capital Region of Jakarta in 2018-2021

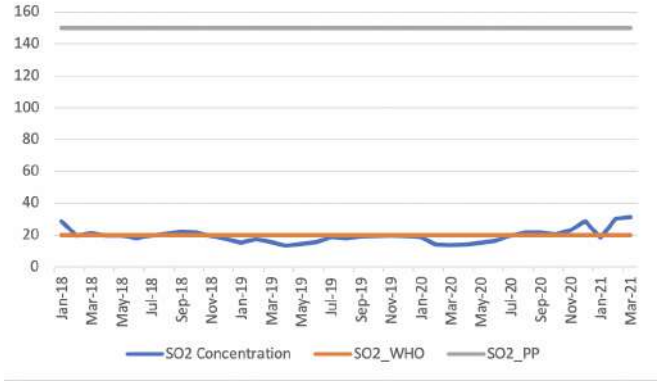

Figure 2. Monthly SO_2 Concentrations in the Special Capital Region of Jakarta in 2018-2021

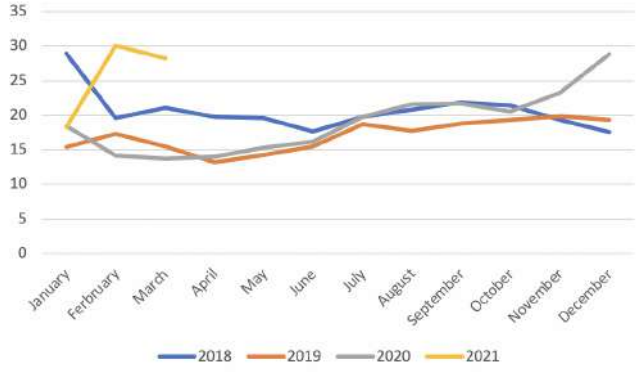

Figure 3. Seasonal SO_2 Concentrations in the Special Capital Region of Jakarta in 2018-2021

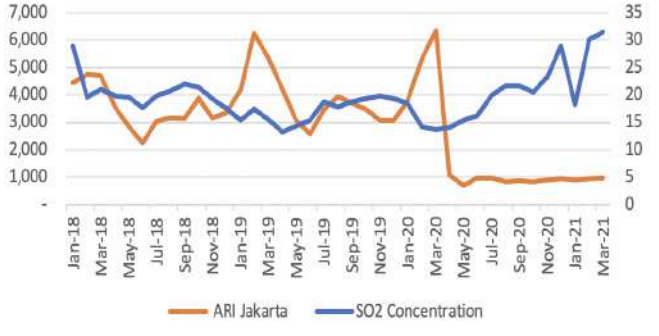

Figure 4. Relationship between SO_2 Concentration and ARI in Children under Five in the Special Capital Region of Jakarta by Season in 2018-2021

Table 2. Association between SO_2 Concentration and Acute Respiratory Infection in Children under Five in Jakarta at Lag 0 Month and Lag 1 Month by Seasons in 2018-2021

Year	Lag = 0			Lag = 1		
	r	p-value	Statistic test	r	p-value	Statistic test
2018	-0.32	0.32	Spearman	0.52	0.02	Spearman
Rainy season	0.67	0.15	Pearson	0.34	0.52	Pearson
Dry season	-0.43	0.39	Pearson	0.84	0.04	Pearson
2019	-0.05	0.87	Pearson	0.05	0.87	Pearson
Rainy season	0.07	0.89	Pearson	0.64	0.17	Pearson
Dry season	-0.97	0.001	Pearson	0.83	0.04	Spearman
2020	-0.57	0.05	Spearman	0.35	0.26	Spearman
Rainy season	-0.25	0.64	Pearson	0.22	0.67	Pearson
Dry season	0.85	0.03	Pearson	0.20	0.7	Pearson
2021	1	-	Spearman	0.5	0.67	Spearman
2018-2021	-0.34	0.04	Spearman	0.24	0.14	Spearman

more insights from the analysis, the data of lag = 0 was provided for comparison. The lag = 1 correlation test between SO_2 concentrations and the number of cases of ARI in 2018 showed a moderate positive relationship (r = 0.52; p-value = 0.02) for the entire year and a solid positive relationship for the dry season (r = 0.84; p-value = 0.04). In 2019, a solid positive relationship was found in the dry season (r = 0.83; p-value = 0.04) (Table 2).

Discussion

This study showed that the highest monthly cases of ARI in children under five from January 2018 to March 2021 occurred in March 2020. In contrast, the highest monthly SO_2 concentration occurred in March 2021. The SO_2 concentration was shown to have an insignificant relationship with the occurrence of ARI in children at lag = 1 month in Jakarta in 2018-2021. The SO_2 concentration significantly correlated with the incidence of ARI in children in 2018. This study was in parallel with a study conducted in Shenzhen, China, which showed no association between monthly SO_2 concentrations and monthly ARI incidence.[14] This pattern of events followed fluctuations and meteorology for SO_2 in the previous month (lag = 1 month).[15] In contrast, this finding was not in line with a study conducted in Hong Kong, which showed a significant association between the number of daily ARI consultations at health services and the concentration of SO_2, even though air pollution may cause substantial morbidity and increase the burden of health services.[16]

The burden of morbidity and mortality caused by air pollution is costly because most pollution-related deaths occur within 1–2 years of exposure.[17] Based on the Regulation of the Minister of Health of the Republic of Indonesia Number 1077 of 2011 Concerning Guidelines for Sanitary Air in Home Spaces, the maximum level of SO_2 required is 0.1 ppm or 261.75 g/Nm.[18] SO_2 is associated with several adverse effects on the respiratory system and other environmental issues.[19] Children are exposed to air containing SO_2 gas daily, which can irritate the respiratory system.[3] This study showed a monthly concentration average SO_2 of 19.48 g/m^3, with the lowest concentration of 13.22 g/m^3 and the highest concentration of 31.46 g/m^3. However, this average concentration of SO_2 was below the air quality standard for SO_2 (150 g/m^3) according to the Indonesian Government Regulation Number 22 of 2021 Concerning the Implementation of Environmental Protection and Management.[20] A study by Putra, *et al.*, stated that SO_2 pollution significantly correlated with the incidence of ARI, with a solid positive relationship.[21] A study conducted in 32 major cities in China also reported that air pollution had a significant relationship with the incidence of respiratory mortality.[22] Another study also revealed an association between air pollution levels and cardiovascular and respiratory disease mortality.[23] In brief, SO_2 pollution will impact respiratory tract irritation.

Conclusion

The number of ARI cases in children under five in Jakarta from January 2018 to March 2021 is sloping in 2021. Males are found to suffer from ARI compared to females. The SO_2 concentration and the occurrence of ARI in children under five in Jakarta from 2018 to 2021 showed a weak relationship. It may be because children under five in Jakarta spent their time indoors rather than outdoors, exposing them to fewer transportation emissions.

Abbreviations

ARI: Acute Respiratory Infection; WHO: World Health Organization; UNICEF: United Nations International Children's Emergency Fund; IDHS: Indonesian Demographic and Health Survey; AQMS: Air Quality Monitoring System; SD: Standard Deviation; CI: Confidence Interval.

Ethics Approval and Consent to Participate

This study was approved by the Research and Community Engagement Ethical Committee, Faculty of Public Health, Universitas Indonesia, No. 10/UN2.F10.D11/PPM.00.02/2021.

Competing Interest

The authors declare that there is no significant competing financial, professional, or personal interest that might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

The data available is only data that has been written in the manuscript, because other data are limited by research ethics.

Authors' Contribution

PAL conducted the data analysis, data interpretation, and drafting of the manuscript. BH contributed substantially to the concept, work design, and manuscript drafting. BH and PAL screened the title and abstract, and BH revised the manuscript critically for the important intellectual content of PAL. BH approved the final version to be published.

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