Impact of Air Pollution on Outpatient Visits for Acute Respiratory Infection in Bukit Rambai, Melaka and Muar, Johor

Noor Aniza Ibrahim[1]*, Shamarina Shohaimi[1], Juliana Jalaludin[2], Mohd Noor Hisham Mohd Nadzir[1]

[1]Department of Biology, Faculty of Science, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

[2]Department Of Environmental and Occupational Health, Faculty of Medicine & Health Sciences, Universiti Putra Malaysia, Serdang, Selangor, Malaysia

***Corresponding Author**

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ABSTRACT

Numerous studies have shown that air pollution disproportionately affects children and the elderly. This study aimed to identify the main age group of patients who suffered from acute respiratory infection due to air pollution in Bukit Rambai, Melaka and Muar, Johor in 2015 to 2018. Data were analyzed using Pearson's rank correlation coefficient by Statistical Product and Service Solutions software. Secondary data were acquired from the State Health Department and the Department of Environment through outpatient visit data on acute respiratory infection (ARI) at Klinik Kesihatan Bandar Maharani (KKBM) and Klinik Kesihatan Bukit Rambai (KKBR), as well as continuous air quality monitoring stations at SMK Bukit Rambai, Melaka, and Kolej Vokasional Muar, Johor. Except for NO_2 and CO, API and other pollutants were associated with daily ARI outpatient visits in Bukit Rambai. API was negatively and significantly correlated with all pollutants except PM_{10} and ARI outpatient visits in Muar. KKBR saw 18,317 ARI outpatients and KKBM 181,212, predominantly 13-59-year-olds. This study shows that API had a positive association with ARI outpatient visits in the 13-59 age group in both study locations. This shows that air pollution may affect adult respiratory health more than previously anticipated. Further studies ought to look at the association between air pollution and ARI in different age groups and how it causes respiratory problems. ARI in high-risk populations can be reduced with tailored interventions using this data.

Keywords: Air Pollution; Air Pollution Index; Acute Respiratory Infection; Outpatient Visits; ambient air pollutants

INTRODUCTION

Air is polluted when a particular part of the troposphere or stratosphere deviates in quality from a norm in contains substances at concentrations (Carlsen et al., 2021) and may be harmful to human health even at low levels (Carvalho, 2021). Children's risk of having acute respiratory infection (ARI) symptoms is reported to be higher in Senegal when exposed to specific elevated NO_2 levels (Kawano et al., 2022), but a study conducted focuses on the regional setting of Selangor State by Mabahwi (Mabahwi et al., 2018) that the incidence of ARI was not shown to be related to air quality. However, in two out of five research districts in Selangor State, there was a significant relationship between exposure to air pollution and respiratory health (Mabahwi et al., 2018). Air pollution is widespread, and research should not be restricted to a particular place. This study aimed to determine how air pollution affects age-related increases in outpatient visits for ARI throughout four years (2015–2018) in the study areas; Bukit Rambai, Melaka and Muar, Johor. This study offers a more in-depth picture of the relationship between the air pollution index and outpatient visits for ARI in a specific age group.

MATERIAL AND METHODS

Air Quality

Secondary data on Malaysian air quality from the Department of Environment (DOE) were used for the period 2015-2018 on hourly concentrations of air pollution index (API), particulate matter (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) (NEHAP, 2020). However, $PM_{2.5}$ was not included in this study because its concentration has only been considered in the computations of the Malaysian API from August 2018. This study selected Kolej Vokasional Muar, Johor (KVM) and SMK Bukit Rambai, Melaka (SMKBR) air monitoring stations. KVM air quality index data was available till March 13, 2018, as the monitoring station is no longer in service. All 2017 monitoring station data were incomplete since April to June data were cancelled owing to concessionaire company changes.

Data on Outpatient Visits

Data on ARI was obtained from daily visit reports from 2015 to 2018 at the selected health facilities were Klinik Kesihatan Bandar Maharani, Johor (KKBM) and Klinik Kesihatan Bukit Rambai, Melaka (KKBR). ARI cases with a duration of less than 14 days were identified using the patients' reported symptoms of ARI, such as throat irritation, nasal block, cough, nasal discharge, sore throat and loss of voice (Meltzer et al., 2010). The age range was based on Malaysia's Ministry of Health's monthly report formatting.

Data Analysis

Descriptive Analysis.

Data in this study were analyzed using Statistical Product and Service Solutions (SPSS) 28. The main age group of air pollution-related ARI patients and the frequency of ARI visits at KKBR and KKBM were described in descriptive analysis. The number of ARI outpatient visit days is N. Another descriptive analysis looked at the mean (M) and standard deviation (SD) for ARI outpatient by age. Three age categories have been set out: <12, 13-59, and >60.

Statistical analysis

Pearson's correlation coefficient analysis was utilised to investigate the association between ARI outpatient visits at KKBR and KKBM and API, SO_2, NO, O_3, CO, and PM_{10}. One-way ANOVA was performed to compare age groups with outpatient visit frequency. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Descriptive Analysis of API, PM_{10}, SO_2, NO_2, O_3, CO and Outpatient Visits at the Study Areas From 2015-2018

Table 1 shows that PM_{10} had a mean and standard deviation value higher than API, CO, O_3, NO_2 and SO_2 in Bukit Rambai, Melaka while Table 2 shows that PM_{10} had a mean and standard deviation value higher than API, CO, O_3, NO_2, and SO_2 in Muar, Johor.

Table 1. Descriptive Analysis of Pollutants and Outpatient Visits at Bukit Rambai, Melaka from 2015-2018

	N	Min	Max	M ± SD
API	17119	18	194	56.46 ± 18.66
PM_{10}	17210	0	338	60.32 ± 32.60
SO_2	17000	0	0	0.00 ± 0.002
NO_2	16967	0	0	0.02 ± 0.01

O_3	16984	0	0	0.05 ± 0.02
CO	16945	0	10	1.05 ± 0.39
Outpatient Visits	17257	1	81	23.45 ± 10.95

Note. API = Air Pollutants Index; PM_{10} = Particulate Matter <10 micron; SO_2 = Sulphur Dioxide; NO_2 = Nitrogen Dioxide; O_3 = Ozone; CO = Carbon Monoxide

Table 2. Descriptive Analysis of Pollutants and Outpatient Visits at Muar, Johor from 2015-2018

	N	**Min**	**Max**	**M ± SD**
API	109540	0	153	44.24 ± 20.11
PM_{10}	109976	0	256	39.22 ± 35.85
SO_2	107598	0	0	0.01 ± 0.01
NO_2	109976	0	0	0.02 ± 0.01
O_3	109976	0	2	0.21 ± 0.33
CO	109976	0	108	9.72 ± 16.92
Outpatient Visits	109976	6	640	196.63 ± 106.26

Note. API = Air Pollutants Index; PM_{10} = Particulate Matter <10 micron; SO_2 = Sulphur Dioxide; NO_2 = Nitrogen Dioxide; O_3 = Ozone; CO = Carbon Monoxide

Association between API, PM_{10}, SO_2, NO_2, O_3, CO and Outpatient Visits at the Study Areas From 2015-2018

Pearson correlation analysis examined the relationships between API, PM_{10}, SO_2, NO_2, O_3, CO and outpatient visits at KKBR and KKBM from 2015-2018. The results of the analysis were shown in the Table 3 and Table 4.

Table 3. Correlation between API, PM_{10}, SO_2, NO_2, O_3, CO and Outpatient Visits at Bukit Rambai, Melaka between 2015 to 2018

	API	PM_{10}	SO_2	NO_2	O_3	CO	Outpatient Visits
API	1						
PM_{10}	.673**	1					
SO_2	.081**	.048**	1				
NO_2	.326**	.417**	-.047**	1			
O_3	.496**	.296**	.236**	.181**	1		
CO	.197**	.245**	.068**	.288**	.124**	1	
Outpatient Visits	.134**	.043**	.226**	-.100**	.035**	-.047**	1

**Correlation is significant at the 0.01 level (2-tailed) ($p<0.01$).

Note. API = Air Pollutants Index; PM_{10} = Particulate Matter <10 micron; SO_2 = Sulphur Dioxide; NO_2 = Nitrogen Dioxide; O_3 = Ozone; CO = Carbon Monoxide

Table 4. Correlation between API, PM_{10}, SO_2, NO_2, O_3, CO and Outpatient Visits at Muar, Johor between 2015 to 2018

	API	**PM_{10}**	**SO_2**	**NO_2**	**O_3**	**CO**	**Outpatient Visits**
API	1						
PM_{10}	.249**	1					
SO_2	.055**	-.377**	1				
NO_2	.273**	-.272**	.535**	1			
O_3	.315**	-.404**	.547**	.631**	1		
CO	.054**	-.385**	.674**	.633**	.577**	1	
Outpatient Visits	-.077**	.178**	-.414**	-.283**	-.152**	-.326**	1

**Correlation is significant at the 0.01 level (2-tailed) ($p<0.01$).

Note. API = Air Pollutants Index; PM_{10} = Particulate Matter <10 micron; SO_2 = Sulphur Dioxide; NO_2 = Nitrogen Dioxide; O_3 = Ozone; CO = Carbon Monoxide

Descriptive and One-way ANOVA Analysis on the Main Age Group of Patients Suffered ARI at Klinik Kesihatan Bukit Rambai, Melaka from 2015-2018.

Table 5 reveals that in 2015-2017, outpatient visits in the 13-59 age range were higher than those in the <12 and >60 age ranges, except in 2018, where >60 outpatient visits were higher than 13-59 and <12 at KKBR. Table 5 indicates that in 2015 in KKBM, outpatient visits were greater for those aged 13-59 compared to those aged >60 and <12. In 2016, outpatient visits were greater for those aged >60 compared to those aged 13-59 and <12. In 2017, outpatient visits were greater in the 13-59 age group compared to those over 60 and <12. In 2018, outpatient visits were greater among ages <12 compared to >60 and 13-59 age groups.

Table 5. Means and standard deviations on the main age group of patients who suffered ARI at Klinik Kesihatan Bukit Rambai, Melaka and Klinik Kesihatan Bandar Maharani, Johor from 2015-2018.

			Daily Outpatient Visits KKBR	Daily Outpatient Visits KKBM	
Year	**Age Range**	***N***	***Mean ± SD***	***N***	***Mean ± SD***
2015	<12	1583	$8.80_b \pm 4.44$	7486	$33.83_a \pm 16.09$
	13-59	2127	$10.97_c \pm 4.83$	14308	$79.67_c \pm 63.16$
	>60	774	$6.28_a \pm 2.74$	4101	$42.53_b \pm 36.24$
2016	<12	2246	$11.24_b \pm 4.48$	6256	$29.69_a \pm 15.24$
	13-59	2816	$13.32_c \pm 4.58$	13738	$71.73_c \pm 52.25$
	>60	114	$2.63_a \pm 1.18$	3906	$46.63_b \pm 61.06$
2017	<12	1468	$9.61_b \pm 5.97$	14374	$58.97_a \pm 20.23$
	13-59	2338	$13.05_c \pm 6.38$	31921	$125.02_c \pm 35.46$
	>60	327	$2.80_a \pm 1.11$	15448	$65.84_b \pm 26.04$
2018	<12	1877	$10.14_a \pm 5.46$	18341	$33.83_b \pm 16.09$
	13-59	2082	$12.37_b \pm 7.26$	32558	$79.67_c \pm 63.16$
	>60	565	$10.75_a \pm 19.22$	18775	$42.53_a \pm 36.24$

Note. Means with different subscripts differ at the p=0.05 level by Duncan's new multiple-range test

The one-way ANOVA in Table 7 demonstrated a statistically significant age difference across at least three goups in KKBR. Based on the Bonferroni test for multiple comparisons, the mean value for the age group under 12 differed significantly from that of the age groups 13–59 and >60. KKBR reported more outpatient visits for ARI in the 13-59 age range compared to <12 and >60. While Table 8 showed a statistically significant age difference between at least three groups in KKBM. The mean value of the <12 age group was substantially different from the 13-59 and >60 age groups using Bonferroni test for multiple comparisons. KKBM reported more outpatient visits for ARI in the 13-59 age range compared to <12 and >60.

Table 7. Analyses for the Age Groups of Outpatients Visits for Acute Respiratory Infection at Klinik Kesihatan Bukit Rambai from 2015-2018.

Measure	**<12**	**13-59**	**>60**	**F ratio**	**p**	**η2**
	M ± SD	**M ± SD**	**M ± SD**			
Age Groups	10.08b ± 5.15	12.51c ± 5.86	6.82a ± 11.39	720.57*	<.001	0.08

Note. Means with different subscripts differ at the p=0.05 level by Duncan's new multiple range test.

Table 8. Analyses for the Age Groups of Outpatients Visits for Acute Respiratory Infection at Klinik Kesihatan Bandar Maharani from 2015-2018.

Measure	**<12**	**13-59**	**>60**	**F ratio**	**p**	**η2**
	M ± SD	**M ± SD**	**M ± SD**			
Age Groups	53.38_a ± 31.55	104.88_c ± 52.75	63.58_b ± 37.88	17448.19*	<.001	0.22

Note. Means with different subscripts differ at the p=0.05 level by Duncan's new multiple range test.

Figure 1 shows that 13-59-year-olds in KKBR had the most outpatient visits in 2016 (5,176), followed by 2018 (4,524), 2015 (4,484), and 2017 (4,133). Figure 2 shows that 2018 (69,674) had the most outpatient visits in KKBM, followed by 2017 (61,743), 2016 (25,895), and 2015 (23,900). The age group of 13-59 years old had the most outpatient visits.

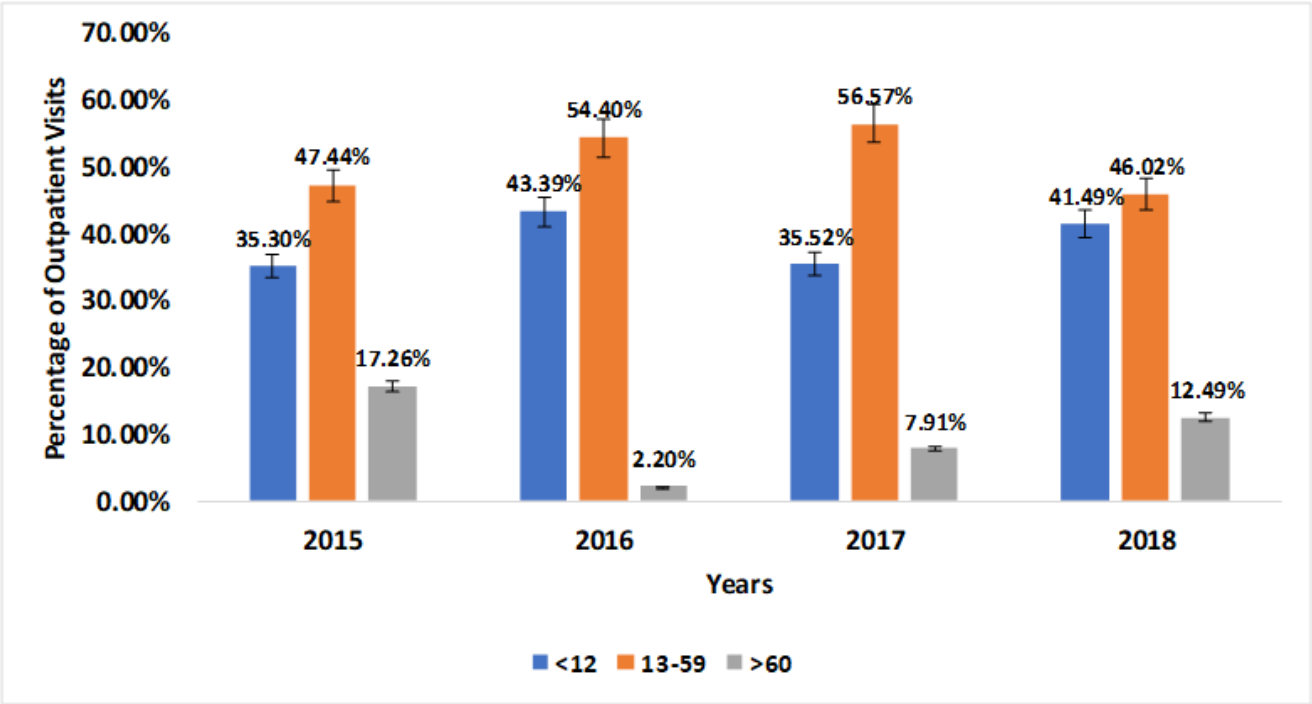

Figure 1. Percentage distribution of outpatient visits based on the main age group of patients who suffered acute respiratory infection at Klinik Kesihatan Bukit Rambai, Melaka, 2015-2018.

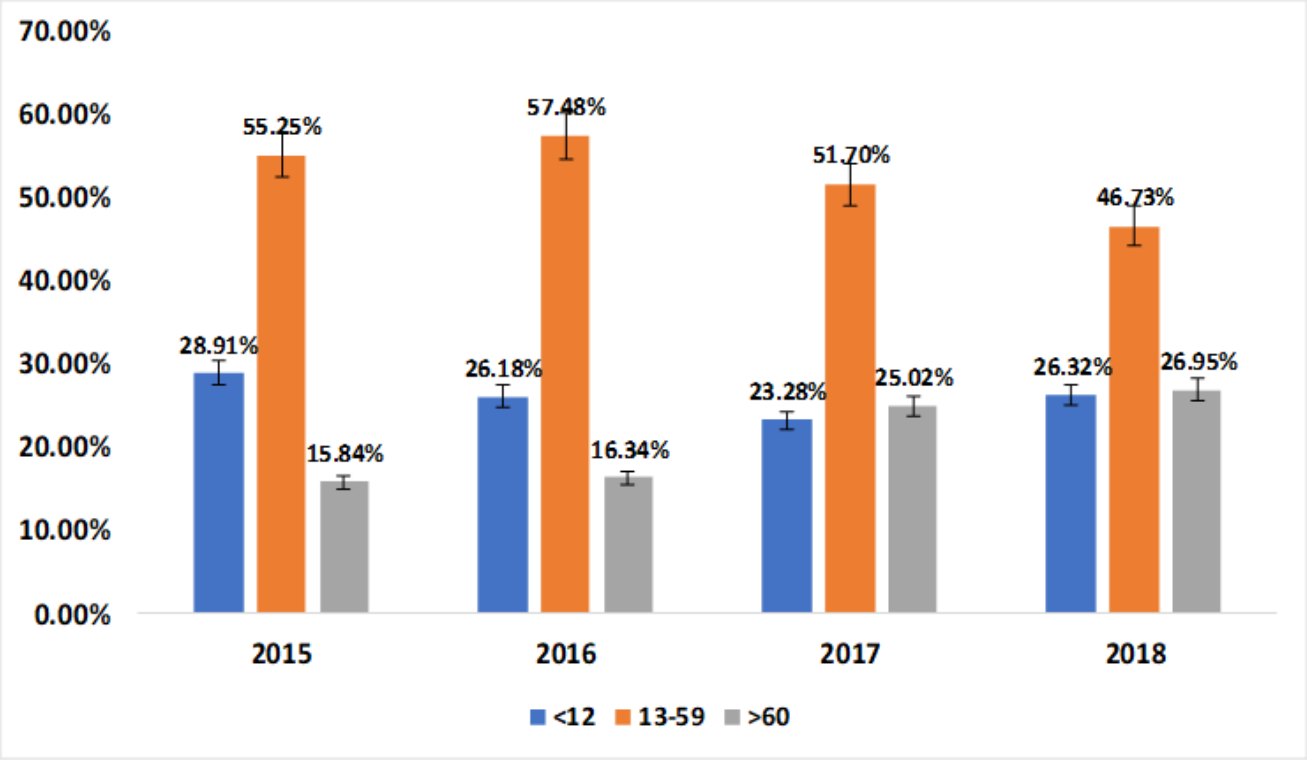

Figure 2. Percentage distribution of outpatient visits based on the main age group of patients who suffered acute respiratory infection at Klinik Kesihatan Bandar Maharani, Muar 2015-2018

The SMKBR and KVM air monitoring stations are located in residential and industrial areas, respectively. As stated by Abdullah (M. H. Abdullah et al., 2016), the majority of air pollution comes from the combustion of fossil fuels. Except for NO_2 and CO, API and other pollutants correlated positively with acute respiratory illness outpatient visits. The strongest relationship was between API and PM_{10}. A positive correlation between API and PM_{10} can also be explained by a study by Hanafi (Hanafi et al., 2018), which identified a direct association between the PM_{10} concentration and API in Johor in 2014 and 2015 and the number of cases of upper respiratory tract infections. PM_{10} is the main source of API fluctuation and air pollution measures, according to Zhang (Y. Zhang et al., 2021) and Azid (Azid et al., 2016). As Szyszkowicz (Szyszkowicz et al., 2018) observed, short-term air pollution exposure can increase emergency department visits for upper and lower respiratory diseases even at low levels, explaining the negative and significant association between SO_2 and CO with daily outpatient visits.

API, SO_2, NO_2, O_3, and CO, except PM_{10}, were negatively and significantly correlated with outpatient visits in KKBM. In the majority of case studies, PM_{10} was a prominent feature of air pollution (Y. Zhang et al., 2021), (Li et al., 2023). The negative correlation of pollutants with outpatient visits from this study could be explained using a study by Szyszkowicz (Szyszkowicz et al., 2018), which showed that short-term exposure to pollution can increase the incidence of emergency room visits for upper and lower respiratory diseases.

There was also a significant positive correlation between API and other pollutants, between SO_2 with CO, NO_2, and O_3, between NO_2 with O_3 and CO, and between O_3 with CO. The significant correlations suggested that the sources of the pollutants may be related or overlap (Mohamad Jamil et al., 2020), (Pius Lee, Rick Saylor, 2018). Moreover, there was a negative and significant correlation for PM_{10} with SO_2, NO_2, O_3, and CO. In contrast to the study by Chang (Chang Hian Wui et al., 2018), the PM_{10} data continuously showed high associations with traffic-related gaseous pollutants; NO_2, and CO, with the exception of SO_2 and O_3.

In Muar, Johor, the strongest relationship was observed between CO and SO_2. This was consistent with a study conducted in Petaling Jaya, Selangor, which discovered a positive significant correlation between CO and SO_2 by Azmi (Azmi et al., 2010) citing the influence of heavy traffic. Muar is one of Johor's major cities. According

to statistics, Johor ranked third in 2019 and 2020 with new motor vehicle registrations, behind Selangor and Wilayah Persekutuan (Ministry of Transport Malaysia, 2021).

Outpatient visits and pollutants and each pollutant's interaction with the others had positive and negative, statistically significant relationships in all study areas. There was a slightly contradictory result in the study areas because different areas may have different constituents of pollutants based on production and local activities. Since different ambient conditions, such as haze and non-haze days, and geographic locations, such as semi-rural and rural areas, are strongly influenced by numerous anthropogenic and natural variables, will presented varying gas levels (N. S. Abdullah et al., 2018).

These two sentinel clinics received the highest proportion among the 13-59 years old age range, followed by <12 and >60. Due to their underdeveloped immune systems, lungs, and metabolic systems, children are especially vulnerable to the detrimental health impacts of air pollution (J. T. Lee, 2021). All the identified studies ran afoul of this study's conclusion that the highest proportion of outpatient visits for ARI was among the 13 to 59 years old. Youth were more likely to seek treatment than the elderly due to the rely on family and were less aware of current events. Despite being aware with media young people not be able to sort through worthless material or recognise the need for treatment (Aamir et al., 2022). Adults are prone to air pollution because they are proportionally exposed to environmental pollutants when working. Numerous studies link pollution to older and younger people's lung function status, while adult lung function status is linked to $PM_{2.5}$ (Xu et al., 2022), (Aretz et al., 2021) but unable to account in this study.

A one-way ANOVA was performed to compare the three different age groups of outpatient visits for ARI at KKBR and KKBM. For the two clinics, the outpatient visits for ARI varied significantly by age group. The age range of 13-59 exhibited outpatient visits for ARI compared to <12 and >60 in both study areas. Symptoms and age had distinct effects on healthcare-seeking behavior [38-40]. This study contradicted Zhang (Q. Zhang et al., 2020), who reported that elderly people >55 with fever, sore throat, and headache had a substantially greater consultation rate than other age groups. Likewise, a national survey of early treatment-seeking behaviour among those with incident severe acute respiratory syndrome coronavirus infection discovered that those over 65 had a higher likelihood of seeking treatment (Kojima et al., 2022). A study by Barua (Barua et al., 2017) indicated that 56.1% of the elderly had the right attitude toward obtaining medical care, while others were driven to self-medicate due to financial constraints.

Despite having the most high-risk areas, Tamil Nadu mothers' awareness of ARI in children and treatment-seeking behaviour were positively correlated (Challa et al., 2016) contradictory with study in Indonesia which 25% of Indonesian children under 5 with ARI symptoms in 2012–2017 study did not receive medical treatment (Titaley et al., 2020). Other cases reported the proportion of people using a hospital to initiate care was 40% among those aged 18-59 and 28% among those aged >60 (Gabrani et al., 2021). Paternal education, religion, residency area, age, and female empowerment greatly affected care-seeking (Abdulkadir & Abdulkadir, 2017). The decision to handle a severe sickness at home, with or without pharmacy medication, or to visit a government or private clinic are some of the reasons for choosing against going to the hospital (Q. Zhang et al., 2020) (Praptiningsih et al., 2016).

CONCLUSIONS

All the pollutants have positive and negative significant correlations with outpatient visits. Most outpatient visits for ARI between 2015 and 2018 were among 13-59 years old patients, followed by the young under 12 and elderly over 60. Age and symptoms showed different influences on healthcare-seeking behaviour. Data from two government clinics may not fully capture air pollution's effects. To expand on prior research on acute respiratory infections and outpatient visits, this study was conducted. Understanding the spatial variations of ambient air pollution and its impact on health is relevant to prevent and to control air pollution.

Although this study highlighted the significant correlations between air pollution and ARI outpatient visits across different age groups, particularly for individuals aged 13-59, it also emphasized the need for further

research to explore the nuanced impacts of specific pollutants like $PM_{2.5}$, which was not included in this study. Moreover, the role of non-pollutant factors such as pre-existing conditions like tuberculosis, cancer, or bacterial infections should be better understood, as these may also contribute to the incidence of ARI. Additionally, understanding the spatial variations of air pollution, taking into account geographic, socioeconomic, and environmental factors, could improve targeted interventions and guide policies aimed at mitigating the public health impact of air pollution on respiratory diseases.

This way, the gap related to the interaction between air pollution and other factors contributing to ARI, such as non-pollutant diseases, is more explicitly highlighted.

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ETHICAL APPROVAL

This study does not require ethical approval as it does not involve the use of human or animal subjects.

Authors' contribution

The study was conceived and designed by Noor Aniza Ibrahim, Shamarina Shohaimi, Juliana Jalaludin, and Mohd Noor Hisham Mohd Nadzir. Noor Aniza Ibrahim performed the material preparation and data collection, and conducted the data analysis under the supervision of Shamarina Shohaimi, Juliana Jalaludin, and Mohd Noor Hisham Mohd Nadzir. The first draft of the manuscript was written by Noor Aniza binti Ibrahim, and Shamarina Shohaimi, Juliana Jalaludin, and Mohd Noor Hisham Mohd Nadzir provided comments. All authors read and approved the final manuscript.

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