A Comparative Analysis of Air Pollutants and Acute Respiratory Infection Outpatient Visits in Selected Areas of Melaka and Johor

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ABSTRACT

Ambient air pollution is an important environmental health concern associated with respiratory morbidity. This study examined the association between major air pollutants and outpatient visits for acute respiratory infection (ARI) in Bukit Rambai, Melaka; Muar, Johor; and Bandar Penawar, Johor, from 2015 to 2018. Hourly concentrations of particulate matter with a diameter of 10 micrometres or less (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), and Air Pollutant Index (API) values were obtained from the Department of Environment Malaysia, while daily ARI outpatient data were obtained from selected health clinics representing each study area. As the data were not normally distributed, Spearman rank-order correlation analysis was used to assess the associations. Significant relationships were observed between air quality indicators and ARI outpatient visits across all three locations. In Bukit Rambai, SO_2 showed the strongest positive association with ARI outpatient visits ($r_s = .226$), while PM_{10} was positively associated with ARI visits in Muar ($r_s = .178$) and showed the strongest positive association in Bandar Penawar ($r_s = .487$). Overall, PM_{10} was the only pollutant that consistently demonstrated a significant positive association with ARI outpatient visits across all three study areas. The findings indicate that the relationship between ambient air pollution and respiratory healthcare utilisation varies according to local environmental and geographical characteristics.

Keywords: ambient air pollution, acute respiratory infection, outpatient visits, PM_{10}, Spearman correlation, Malaysia.

INTRODUCTION

This study investigates the major air pollutants associated with outpatient visits for acute respiratory infection (ARI) in Bukit Rambai, Melaka, and Muar, Johor, with Bandar Penawar, Johor, selected as a comparative site. Bukit Rambai and Muar are coastal areas located along the Strait of Malacca, whereas Bandar Penawar is situated on the southeastern coast of Peninsular Malaysia facing the South China Sea. These geographical differences may influence local air pollution patterns due to variations in meteorological conditions, pollutant transport, emission sources, and the occurrence of haze episodes.

Air pollutant concentrations may vary considerably according to environmental conditions, including haze and non-haze periods, as well as differences in geographical and settlement characteristics such as semi-rural and rural environments. These variations are influenced by both natural processes and anthropogenic activities (Nadiah et al., 2018). Understanding these differences is important when assessing the potential short-term health effects of air pollution across locations with different environmental settings.

Outpatient visits were selected as the health outcome indicator because they may provide a more sensitive measure of acute or short-term respiratory effects associated with exposure to air pollutants compared with hospital admissions, particularly for less severe respiratory conditions that are commonly managed at primary healthcare facilities (Guo et al., 2021). Therefore, outpatient attendance for ARI provides a relevant indicator for examining possible changes in respiratory morbidity associated with fluctuations in ambient air quality.

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To achieve the study objective, correlation analysis was conducted to examine the relationship between the Air Pollutant Index (API), particulate matter with a diameter of 10 micrometres or less (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO), and outpatient visits for ARI in Bukit Rambai, Melaka; Muar, Johor; and Bandar Penawar, Johor. The comparison across these three locations provides an opportunity to assess whether differences in geographical setting and ambient air pollution patterns are associated with variations in ARI outpatient visits.

METHODOLOGY

Air Quality Data

This study utilised hourly concentrations of major air pollutants measured by the Department of Environment (DOE) from 2015 to 2018, namely particulate matter with a diameter of 10 micrometres or less (PM_{10}), ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO). Particulate matter with a diameter of 2.5 micrometres or less ($PM_{2.5}$) was excluded from the study because it was only incorporated into Malaysia's Air Pollutant Index (API) calculation beginning in August 2018. In addition, air quality records for April to June 2017 were excluded due to the transition between concessionaire companies responsible for air quality monitoring during that period.

Three Continuous Air Quality Monitoring Stations (CAQMS) were selected to represent the respective study areas. The monitoring station located at Kolej Vokasional Muar (KVM) was used to represent the Muar area, the station at Sekolah Menengah Kebangsaan Bukit Rambai (SMKBR) represented Bukit Rambai, and the station at Sekolah Menengah Agama Bandar Penawar (SMABP) represented Bandar Penawar. Geographically, the monitoring stations in Muar and Bukit Rambai are situated on the western side of Peninsular Malaysia and face the Strait of Malacca, while the Bandar Penawar station is located on the southeastern side of Peninsular Malaysia.

Outpatient Visits Data

Data on ARI were obtained from daily outpatient visit reports for the four-year period from 2015 to 2018. The data were collected from three selected health clinics representing the respective study areas: Klinik Kesihatan Bukit Rambai (KKBR), representing Bukit Rambai; Klinik Kesihatan Bandar Maharani (KKBM), representing Muar; and Klinik Kesihatan Bandar Penawar (KKBP), representing Bandar Penawar.

Spearman Rank-Order Correlation

As the sample size exceeded 50 observations ($n>50$), the Kolmogorov–Smirnov test was used to assess the normality of the data distribution. The results indicated that the variables were not normally distributed. Therefore, the Spearman rank-order correlation coefficient was employed as a non-parametric statistical test to examine the strength and direction of the association between outpatient visits for ARI and ambient air quality indicators.

The analysis assessed the relationship between ARI outpatient visits recorded at Klinik Kesihatan Bukit Rambai (KKBR), Klinik Kesihatan Bandar Maharani (KKBM), and Klinik Kesihatan Bandar Penawar (KKBP) and the SO_2, NO_2, O_3, CO, and PM_{10} over the four-year study period from 2015 to 2018. Statistical significance was set at $p < 0.01$.

RESULTS AND DISCUSSION

Spearman's rank-order correlation was run to examine the relationship between API, PM_{10}, SO_2, NO_2, O_3, CO and outpatient visits for ARI at Bukit Rambai, Melaka; Muar, Johor and Bandar Penawar, Johor from 2015-2018.

Table 1. Spearman Rank-Order Correlation between API, PM_{10}, SO_2, NO_2, O_3, CO and ARI Outpatient Visits for ARI at Bukit Rambai from 2015-2018.

	API	PM_{10}	SO_2	NO_2	O_3	CO	Outpatient Visits
API	1.000						
PM_{10}	.673**	1.000					
SO_2	.081**	.048**	1.00				
NO_2	.326**	.417**	-.047**	1.00			
O_3	.496**	.296**	.236**	.181**	1.00		
CO	.197**	.245**	.068**	.288**	.124**	1.00	
Outpatient Visits for ARI	.134**	.043**	.226**	-.100**	.035**	-.047**	1.000

**. 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; ARI = Acute Respiratory Infection

Table 2. Spearman Rank-Order Correlation between API, PM_{10}, SO_2, NO_2, O_3, CO and ARI Outpatient Visits at Muar from 2015-2018

	API	PM_{10}	SO_2	NO_2	O_3	CO	Outpatient Visits
API	1.000						
PM_{10}	.249**	1.000					
SO_2	.055**	-.377**	1.00				
NO_2	.273**	-.272**	.535**	1.00			
O_3	.315**	-.404**	.547**	.631**	1.00		
CO	.054**	-.385**	.674**	.633**	.577**	1.00	
ARI Outpatient Visits	-.077**	.178**	-.414**	-.283**	-.152**	-.326**	1.000

**. 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; ARI = Acute Respiratory Infection

Table 3. Spearman Rank-Order Correlation between API, PM_{10}, SO_2, NO_2, O_3, CO and ARI Outpatient Visits at Bandar Penawar from 2015-2018

	API	PM_{10}	SO_2	NO_2	O_3	CO	Outpatient Visits
API	1.000						
PM_{10}	.285**	1.000					
SO_2	.177**	-.274**	1.00				
NO_2	.197**	-.400**	.641**	1.00			
O_3	.483**	-.212**	.484**	.539**	1.00		
CO	.273**	-.421**	.518**	.718**	.556**	1.00	
Outpatient Visits for ARI	.074**	.487**	-.172**	-.306**	-.173**	-.460**	1.000

**. 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; ARI = Acute Respiratory Infection

Bukit Rambai, Melaka, comprises both residential and industrial areas. Abdullah et al. (2016) reported that a substantial proportion of ambient air pollution originates from fossil fuel combustion associated with motor vehicles and industrial activities. From 2015 to 2018, Bukit Rambai experienced predominantly good (0–50) and moderate (51–100) Air Pollutant Index (API) levels, with only 37 days classified as unhealthy (101–200).

The Spearman rank-order correlation analysis showed significant associations between all air quality parameters and daily outpatient visits for ARI at $p < 0.01$. Positive correlations were observed between ARI outpatient visits and API ($r_s = .134$), PM_{10} ($r_s = .043$), SO_2 ($r_s = .226$), and O_3 ($r_s = .035$). In contrast, NO_2 ($r_s = -.100$) and CO ($r_s = -.047$) showed significant negative correlations with ARI outpatient visits. Among the pollutants examined, SO_2 demonstrated the strongest positive association with ARI outpatient visits, although the strength of the correlation remained weak.

Among the air quality parameters, the strongest positive correlation was observed between API and PM_{10} ($r_s = .673$). This indicates that higher PM_{10} concentrations were strongly associated with higher API levels during the study period. This finding is consistent with Hanafi et al. (2018), who identified an association between PM_{10} concentration, API levels, and cases of upper respiratory tract infection in Johor in 2014 and 2015. The finding is also consistent with Zhang et al. (2021) and Azid et al. (2016), who identified PM_{10} as an important contributor to API variability and ambient air pollution measurements.

Although this study did not incorporate meteorological factors such as ambient temperature, Mohd Zizi et al. (2018) reported that ambient temperature had the strongest positive correlation with PM_{10} concentration among the meteorological parameters examined. The inclusion of meteorological variables in future studies may therefore provide a more comprehensive explanation of variations in pollutant concentrations and their relationship with respiratory health outcomes.

The significant negative correlations between NO_2 and CO and daily ARI outpatient visits should be interpreted cautiously, as these inverse associations do not necessarily indicate a protective or causal relationship. Szyszkowicz et al. (2018) demonstrated that exposure to air pollution may increase emergency room visits for upper and lower respiratory diseases even under relatively modest levels of ambient air pollution. This suggests that the relationship between air pollutant exposure and respiratory healthcare utilisation may be influenced by multiple environmental, temporal, and population-related factors. Emergency room visits have also been considered within the broader context of outpatient healthcare utilisation in previous studies (Lavergne et al., 2022; Giannouchos et al., 2021).

Muar, Johor, experienced predominantly good (0–50) and moderate (51–100) Air Pollutant Index (API) levels from 2015 to 2018, with only 19 days classified as unhealthy (101–200).

The Spearman rank-order correlation analysis showed significant associations between all air quality parameters and ARI outpatient visits at $p<0.01$. Negative correlations were observed between ARI outpatient visits and API ($r_s = -.077$), SO_2 ($r_s = -.414$), NO_2 ($r_s = -.283$), O_3 ($r_s = -.152$), and CO ($r_s = -.326$). In contrast, PM_{10} showed a significant positive correlation with ARI outpatient visits ($r_s = .178$).

Among the pollutants examined, SO_2 demonstrated the strongest association with ARI outpatient visits, although the relationship was negative. PM_{10} has also been identified as an important air pollutant associated with respiratory health outcomes in previous studies (Zhang et al., 2021; Li et al., 2023).

The negative correlations observed between several pollutants and ARI outpatient visits should be interpreted cautiously and should not be regarded as indicating a protective effect. Szyszkowicz et al. (2018) demonstrated that exposure to air pollution may increase emergency room visits for upper and lower respiratory diseases even under relatively modest levels of ambient air pollution. This suggests that the relationship between ambient pollutant concentrations and respiratory healthcare utilisation may be influenced by multiple environmental, temporal, and population-related factors.

Significant correlations were also observed among the individual air pollutants in Muar. API showed positive correlations with PM_{10}, SO_2, NO_2, O_3, and CO. Positive correlations were also observed between SO_2 and NO_2 (r_s r = .535), SO_2 and O_3 (r_s = .547), SO_2 and CO (r_s = .674), NO_2 and O_3 (r_s = .631), NO_2 and CO (r_s = .633), and O_3 and CO (r_s = .577). In contrast, PM_{10} was negatively correlated with SO_2 (r_s = −.377), NO_2 (r_s = −.272), O_3 (r_s = −.404), and CO (r_s = −.385).

Among the air pollutants, the strongest positive correlation was observed between CO and SO_2 (r_s = .674). This finding is consistent with Azmi et al. (2010), who reported a significant positive correlation between CO and SO_2 in Petaling Jaya, Selangor, and attributed the relationship partly to heavy traffic. Muar is one of the major urban centres in Johor, where vehicular activity may contribute to ambient pollutant concentrations. According to the Ministry of Transport Malaysia (2021), Johor ranked third after Selangor and Wilayah Persekutuan in new motor vehicle registrations, with 42,923 registrations in 2019 and 35,394 in 2020.

Bandar Penawar, Johor, experienced predominantly good (0–50) and moderate (51–100) Air Pollutant Index (API) levels from 2015 to 2018, with only 16 days classified as unhealthy (101–200). The Spearman rank-order correlation analysis showed significant associations between all air quality parameters and ARI outpatient visits at $p < .01$. Positive correlations were observed between ARI outpatient visits and API (r_s = .074) and PM_{10} (r_s = .487). In contrast, SO_2 (r_s = −.172), NO_2 (r_s = −.306), O_3 (r_s = −.173), and CO (r_s = −.460) showed significant negative correlations with ARI outpatient visits. Among the air quality parameters examined, PM_{10} demonstrated the strongest positive association with ARI outpatient visits (r_s = .487).

Significant correlations were also observed among the individual air pollutants. PM_{10} showed significant negative correlations with SO_2 (r_s = −0.274), NO_2 (r_s = −0.400), O_3 (r_s = −0.212), and CO (r_s = −0.421). In contrast, API was positively correlated with SO_2, NO_2, O_3, and CO. Positive correlations were also observed between SO_2 and NO_2 (r_s = 0.641), SO_2 and O_3 (r_s = 0.484), SO_2 and CO (r_s = 0.518), NO_2 and O_3 (r_s = 0.539), NO_2 and CO (r_s = 0.718), and O_3 and CO (r_s = 0.556).

Among the individual air pollutants, the strongest positive correlation was observed between NO_2 and CO (r_s = 0.718). Both CO and NO_2 are commonly associated with combustion processes, particularly emissions from gasoline- and diesel-powered motor vehicles. Other potential sources include generators, propane- or wood-burning cooking and heating appliances, cigarette smoke, and natural events such as lightning and forest fires (Du et al., 2022; Chen et al., 2021; Reumuth et al., 2019; Payus et al., 2019). The strong positive association between NO_2 and CO may therefore reflect the contribution of common combustion-related emission sources in Bandar Penawar.

CONCLUSION

This study demonstrated significant associations between ambient air quality indicators and outpatient visits for ARI across Bukit Rambai, Muar, and Bandar Penawar from 2015 to 2018, although the strength and direction of the associations varied between study areas. In Bukit Rambai, API, PM_{10}, SO_2, and O_3 were positively associated with ARI outpatient visits, with SO_2 showing the strongest positive association (r_s = .226). In Muar, PM_{10} was the only pollutant that showed a positive association with ARI outpatient visits (r_s = .178), while API, SO_2, NO_2, O_3, and CO showed negative associations. In Bandar Penawar, API and PM_{10} were positively associated with ARI outpatient visits, with PM_{10} demonstrating the strongest positive association (r_s = .487).

Overall, PM_{10} was the only pollutant that consistently demonstrated a significant positive association with ARI outpatient visits across all three study areas. However, the variation in correlation patterns between locations indicates that the relationship between ambient air pollution and respiratory healthcare utilisation may differ according to local environmental conditions, emission sources, geographical characteristics, and other contributing factors. As this study was based on correlation analysis, the findings indicate associations rather than causal relationships. Future studies incorporating meteorological variables and other potential confounding factors may provide a more comprehensive understanding of the relationship between ambient air pollution and ARI outpatient visits.

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