Relationship between common air pollutants with risk of cardio-respiratory hospitalization in urbanized areas in Kelantan

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Abstract. A high concentration of air pollution can lead to health problems which are the cardiovascular and respiratory systems (WHO, 2014). A study has been conducted to know the relationship between five criteria air pollutants with hospitalization related to cardiovascular and respiratory diseases in two cities in Kelantan. The secondary data from 2000 until 2015 analyzed in the study were obtained from DOE and MOH for the air pollutants concentration and hospitalization, respectively. This study shows that the mean concentration of all pollutants in the study area is below the RMAAQS. Significant Relative Risk (RR) values were found for cardiovascular hospitalization associated with SO^2 (RR = 1.537, 95% CI = 2.970, 7.956), NO^2 (RR = 1.212, 95% CI = 1.156, 1.272), and O^3 (RR = 4.873, 95% CI = 2.768, 8.578). In contrast, significant RR for respiratory hospitalization was found to be associated with SO^2 (RR = 1.952, 95% CI = 1.013, 3.762), NO^2 (RR = 2.021, 95% CI = 6.170, 6.620), O^3 (RR = 1.128, 95% CI = 4.427, 2.874), and PM^{10} (RR = 1.008, 95% CI = 1.007, 1.008). The highest value of Relative Risk is O^3 and NO^2 for hospitalization related to cardiovascular and respiratory diseases, respectively. In conclusion, the value of RR associated with air pollutants proves that air pollutants are associated with cardiovascular and respiratory-related hospitalization risk.

1 Introduction

Air pollution issues lead to scholarly debate and public concern as they potentially degrade human health. Most of the air pollution is being created by humans themselves. The sources of air pollution by man-made are burning fossil fuels, transportation, industry, agriculture, open burning, and bushfire [1]. Whereas ash, sulfur dioxide, combustion gases, volcanic, radon, and smog are air pollutants mainly released from natural sources such as forest fires and volcanic eruptions [2]. Apart from the type of emission sources, the meteorological condition also influences the air pollution concentration level. The air pollution movement governed by meteorological parameters such as wind speed and direction also affects the fate of air pollutants. If the air is calm and contaminants cannot disperse, then the concentration of the air pollutants will increase [3].

Air pollution can harm human health, such as its effects on the cardiovascular and respiratory systems. For instance, particulate matter may affect the heart and impair the other function. When the poisonous tiny particles break through the lung, the toxic compound can go deeper into the lung and cause cancer which slides straight into the bloodstream in the body [4]. It also can affect heart disease, which can happen to everyone, especially adults, due to coal combustion that releases pro-inflammatory air pollutants. When the concentration of coal-burning derived air pollutants increases, hospital admissions potentially increase for cardiovascular-related diseases such as acute myocardial infarction, disturbances of heart rhythm, ischemic heart diseases due to insufficient blood supply because of the blocked artery, and congestive heart failure [5]. Thus, this study aims to predict the association of five criteria air pollutants with increased respiratory hospitalization.

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2 Methodology

2.1 Study area and data acquisition

Two study areas were chosen to represent the urbanized area in Kelantan, namely Kota Bharu and Kelantan, based on the locations of three continuous Air Quality Monitoring (CAQM) stations that hourly monitored five criteria air pollutants from 2000 to 2015. The acquired air pollutants and meteorological parameters, namely particulate matter 10 (PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), relative humidity, temperature, and wind speed, were provided by the Department of Environment (DOE). The secondary data on hospitalization was acquired from the Ministry of Health (MOH), specifically for cardiovascular and respiratory-related diseases using National Medical Research Register (NMRR). Cardiovascular and respiratory cases were selected based on the International Classification of Disease, Tenth Revision (ICD-10), coded as I00-I99 and J00-J99, respectively. Detailed study areas and data acquisition were previously published by [6].

2.2 Data processing and analysis

The analysis was conducted to determine the association between air pollutants, which are Particulate Matter 10 (PM_{10}), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Ozone (O_3), and Nitrogen Dioxide (NO_2), and data from patients suffering from cardiovascular and respiratory related diseases. The acquired data was arranged monthly and yearly for each pollutant concentration, meteorological parameter, and patient demographic information before further data analysis, namely descriptive, Pearson correlation, and Poisson regression using SPSS version 23. Poisson regression was executed to identify the Relative Risk of respective morbidity prevalence against the five air pollutants.

3 Results and Discussion

3.1 Descriptive statistics of air pollutants and hospitalization (in yearly arrangement)

Table 1 shows the descriptive statistics of five air pollutants from the Kota Bharu monitoring station from 2000 to 2015 (data for Tanah Merah is not shown). The mean concentration for SO_2, NO_2, O_3, CO and PM_{10} ranged from 0.000 – 0.001 $\mu g/m^3$, 0.00 – 0.01 $\mu g/m^3$, 0.01 – 0.02 $\mu g/m^3$, 0.42 – 0.82 mg/m^3, and 39.64 – 67.55 $\mu g/m^3$, respectively. The concentrations of the air pollutants were found to be lower than the Malaysian Ambient Air Quality Standard (MAAQS, IT-1 2015) except for PM_{10} in the year 2015. Among all the air pollutants, PM_{10} was found to dominate the trend followed by CO. This could be due to the location of Kota Bharu, the major city in Kelantan that increasingly receives a high number of vehicles. Many particles are released during the traffic due to the combustion of fossil fuels, which makes the concentration of PM_{10} higher than other pollutants [6]. The high motor vehicles emission also can increase the concentration of CO. [7] stated that the composition of particulate matter is from carbonaceous particles with associated adsorbed organic chemicals and also under oxidation reaction of precursor gaseous such as nitrates, sulfates, and polycyclic aromatic hydrocarbons.

Table 1. Average concentration of air pollutants recorded for the period 2000 -2015 at Kota Bharu air monitoring station.

	SO_2 (μg/m³)		NO_2 (μg/m³)		O_3 (μg/m³)		CO (mg/m³)		PM_{10} (μg/m³)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2000	0.002	0.001	0.01	0.002	0.01	0.002	0.82	0.1	39.64	8.6
2001	0.002	0.001	0.01	0.002	0.01	0.002	0.79	0.1	42.72	9.0
2002	0.001	0.000	0.01	0.001	0.01	0.002	0.76	0.1	41.42	7.8
2003	0.001	0.001	0.01	0.001	0.01	0.003	0.78	0.1	40.78	7.5
2004	0.001	0.001	0.01	0.002	0.01	0.003	0.80	0.1	46.29	9.9
2005	0.001	0.001	0.01	0.001	0.01	0.003	0.74	0.1	41.17	6.3
2006	0.001	0.000	0.01	0.001	0.02	0.002	0.67	0.1	40.34	7.7
2007	0.001	0.000	0.01	0.001	0.02	0.001	0.67	0.1	44.97	6.8

2008	0.001	0.000	0.01	0.002	0.01	0.003	0.66	0.1	43.53	8.2
2009	0.000	0.000	0.01	0.001	0.01	0.001	0.61	0.1	42.99	6.5
2010	0.001	0.001	0.01	0.001	0.01	0.003	0.59	0.1	41.68	3.6
2011	0.000	0.000	0.01	0.001	0.02	0.003	0.59	0.1	45.93	6.8
2012	0.000	0.000	0.00	0.001	0.01	0.002	0.42	0.0	39.64	7.4
2013	0.000	0.001	0.00	0.001	0.01	0.004	0.46	0.1	41.40	5.5
2014	0.000	0.000	0.00	0.001	0.02	0.002	0.53	0.1	40.93	7.8
2015	0.000	0.001	0.00	0.001	0.02	0.004	0.60	0.1	67.55	15.2

In addition, demographic characteristics for cardiovascular and respiratory-related disease patients are shown in Table 2 and Table 3, respectively. Most cardiovascular-related disease patients were between 40 – 64 years old in both study locations. In contrast, the highest count of respiratory-related disease patients was aged below 19 years old. Males dominated the patient number for cardiovascular or respiratory-related disease, except Tanah Merah recorded that women were slightly higher than males from 2001 to 2005. Malay patients of the cardio-respiratory cases were the highest compared to other races for both locations.

Table 2. Demographic characteristics of cardiovascular-related disease patients in both study locations.

Year	Kota Bharu										Tanah Merah									
	Age, n (%)				Gender, n (%)		Ethnicity, n (%)				Age, n (%)				Gender, n (%)		Ethnicity, n (%)			
	≤19	20-39	40-64	≥65	Male	Female	M	C	I	Other	≤19	20-39	40-64	≥65	Male	Female	M	C	I	Other
2000	68 (3.6)	167 (8.8)	**1001 (52.6)**	669 (35.1)	**1185 (62.2)**	720 (37.8)	**1816 (95.3)**	64 (3.7)	3 (0.2)	22 (1.1)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2001	96 (4.2)	313 (13.6)	**1146 (49.6)**	754 (32.7)	**1317 (57)**	992 (43)	**2194 (95)**	76 (3.3)	12 (0.5)	27 (1.2)	25 (4.6)	74 (13.5)	**264 (48.2)**	185 (33.8)	265 (48.4)	**283 (51.6)**	**535 (97.6)**	13 (2.4)	0	0
2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	20 (4.0)	76 (15.2)	**252 (50.4)**	152 (30.4)	245 (49.0)	**255 (51.0)**	**483 (96.6)**	10 (2.0)	0	7 (1.4)
2003	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	23 (4.3)	68 (12.8)	**256 (48.1)**	185 (34.8)	244 (45.9)	**288 (54.1)**	**519 (97.6)**	11 (2.1)	1 (0.2)	1 (0.2)
2004	85 (3.1)	195 (7.1)	**1404 (50.9)**	1072 (38.9)	**1640 (59.5)**	1116 (40.5)	**2582 (93.7)**	122 (4.4)	9 (0.3)	43 (1.6)	16 (3.6)	63 (14.3)	**234 (53.2)**	127 (28.9)	211 (48.0)	**229 (52.0)**	**423 (96.1)**	14 (3.2)	0	3 (0.7)
2005	67 (2.4)	158 (5.6)	**1490 (53)**	1094 (38.9)	**1616 (57.5)**	1193 (42.5)	**2676 (95.3)**	102 (3.6)	7 (0.2)	24 (0.9)	17 (3.6)	56 (12.0)	**222 (47.5)**	172 (36.8)	233 (49.9)	**234 (50.1)**	**446 (95.5)**	17 (3.6)	2 (0.4)	2 (0.4)
2006	87 (3.1)	185 (6.6)	**1461 (51.9)**	1082 (38.4)	**1682 (59.8)**	1133 (40.2)	**2654 (94.3)**	117 (4.2)	9 (0.3)	35 (1.2)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2007	81 (2.8)	198 (6.9)	**1477 (51.8)**	1095 (38.4)	**1801 (63.2)**	1050 (36.8)	**2699 (94.7)**	103 (3.6)	4 (0.1)	45 (1.6)	15 (3.0)	50 (10.0)	**252 (50.4)**	183 (36.6)	**285 (57.0)**	215 (43.0)	**478 (95.6)**	14 (2.8)	1 (0.2)	7 (1.4)
2008	77 (3.2)	208 (8.5)	**1162 (47.7)**	987 (40.6)	**1535 (63.1)**	899 (36.9)	**2338 (96.1)**	70 (2.9)	2 (0.1)	24 (1.0)	71 (2.6)	275 (10.0)	**1229 (44.8)**	1169 (42.6)	**1407 (51.3)**	1337 (48.7)	**2641 (96.2)**	72 (2.6)	6 (0.2)	25 (0.9)
2009	78 (3.0)	196 (7.5)	**1396 (53.2)**	956 (36.4)	**1675 (63.8)**	951 (36.2)	**2482 (94.5)**	104 (4.0)	0 (0)	40 (1.5)	76 (2.3)	298 (9.1)	**1490 (45.4)**	1419 (43.2)	**1725 (52.5)**	1558 (47.5)	**3159 (96.2)**	91 (2.8)	7 (0.2)	26 (0.8)
2010	85 (2.6)	321 (9.7)	**1786 (54.0)**	1116 (33.7)	**2056 (62.2)**	1252 (37.8)	**3116 (94.2)**	138 (4.2)	8 (0.2)	46 (1.4)	14 (2.9)	17 (3.5)	**285 (58.2)**	174 (35.5)	**279 (56.9)**	211 (43.1)	**472 (96.3)**	14 (2.9)	3 (0.6)	1 (0.2)
2011	84 (2.1)	354 (8.9)	**2281 (57.5)**	1247 (31.4)	**2420 (61.0)**	1546 (39.0)	**3750 (94.6)**	166 (4.2)	12 (0.3)	38 (1.0)	8 (1.2)	29 (4.2)	**342 (49.4)**	313 (45.2)	**390 (56.4)**	302 (43.6)	**674 (97.4)**	13 (1.9)	1 (0.1)	4 (0.6)
2012	286 (9.9)	228 (7.9)	**1528 (53.1)**	834 (29.0)	**1778 (61.8)**	1098 (38.2)	**2745 (95.4)**	98 (3.4)	5 (0.2)	28 (1.0)	8 (1.3)	29 (4.8)	**327 (54.0)**	241 (39.8)	**352 (58.2)**	253 (41.8)	**588 (97.2)**	8 (1.3)	0	9 (1.5)
2013	87 (2.6)	268 (7.9)	**1966 (58.0)**	1067 (31.5)	**2188 (64.6)**	1200 (35.4)	**3260 (96.2)**	106 (3.1)	2 (0.1)	20 (0.6)	17 (3.3)	33 (6.5)	**264 (52.0)**	194 (38.2)	**329 (64.8)**	179 (35.2)	**478 (94.1)**	17 (3.3)	2 (0.4)	11 (2.2)
2014	80 (3.1)	187 (7.4)	**1452 (57.1)**	824 (32.4)	**1646 (64.7)**	897 (35.3)	**2434 (95.7)**	78 (3.1)	5 (0.2)	26 (1.0)	13 (3.7)	20 (5.6)	**204 (57.3)**	119 (33.4)	**240 (67.4)**	116 (32.6)	**334 (93.8)**	7 (2.0)	1 (0.3)	14 (3.9)
2015	73 (2.8)	218 (8.3)	**1462 (55.5)**	881 (33.4)	**1748 (66.4)**	886 (33.6)	**2522 (95.7)**	73 (2.8)	5 (0.2)	34 (1.3)	19 (3.8)	39 (7.8)	**227 (45.4)**	215 (43.0)	**304 (60.8)**	196 (39.2)	**456 (91.2)**	5 (1.0)	2 (0.4)	37 (7.4)

M = Malay, C = Chinese, I = Indian, NA = data not available

Table 3. Demographic characteristics of respiratory-related disease patients in both study locations.

Year	Kota Bharu										Tanah Merah									
	Age, n (%)				Gender, n (%)		Ethnicity, n (%)				Age, n (%)				Gender, n (%)		Ethnicity, n (%)			
	≤19	20-39	40-64	≥65	Male	Female	M	C	I	Other	≤19	20-39	40-64	≥65	Male	Female	M	C	I	Other
2000	**626 (41.7)**	181 (12.1)	358 (23.9)	336 (22.4)	**902 (60.1)**	594 (39.6)	**1452 (96.7)**	33 (2.2)	5 (0.3)	11 (0.7)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2001	**818 (40.6)**	275 (13.7)	486 (24.1)	435 (21.6)	**1126 (55.9)**	888 (44.1)	**1916 (95.1)**	64 (3.2)	11 (0.5)	23 (1.1)	**250 (41.7)**	94 (15.7)	156 (26.0)	100 (16.7)	**293 (48.8)**	307 (51.2)	**591 (98.5)**	5 (0.8)	2 (0.3)	2 (0.3)
2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**295 (46.5)**	88 (13.9)	148 (23.3)	104 (16.4)	**335 (52.8)**	300 (47.2)	**625 (98.4)**	6 (0.9)	1 (0.2)	3 (0.5)
2003	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**387 (46.0)**	101 (12.0)	158 (18.8)	196 (23.3)	**432 (51.3)**	410 (48.7)	**830 (98.6)**	7 (0.8)	1 (0.1)	4 (0.5)
2004	**974 (39.0)**	320 (12.8)	629 (25.2)	573 (23.0)	**1427 (57.2)**	1069 (42.8)	**2403 (96.3)**	52 (2.1)	7 (0.3)	34 (1.4)	**268 (37.4)**	90 (12.6)	179 (25.0)	180 (25.1)	**414 (57.7)**	303 (42.3)	**700 (97.6)**	14 (2.0)	2 (0.3)	1 (0.1)
2005	**1107 (38.8)**	380 (13.3)	743 (26.1)	621 (21.8)	**1625 (57.0)**	1226 (43.0)	**2759 (96.8)**	58 (2.0)	4 (0.1)	30 (1.1)	**422 (52.6)**	85 (10.6)	146 (18.2)	150 (18.7)	**449 (55.9)**	354 (44.1)	**789 (98.3)**	10 (1.2)	2 (0.2)	2 (0.2)
2006	**1155 (38.3)**	388 (12.9)	799 (26.5)	677 (22.4)	**1704 (56.4)**	1315 (43.6)	**2878 (95.3)**	84 (2.8)	8 (0.3)	49 (1.6)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2007	**1293 (41.0)**	333 (10.6)	761 (24.1)	767 (24.3)	**1858 (58.9)**	1296 (41.1)	**3028 (96.0)**	68 (2.2)	4 (0.1)	54 (1.7)	**342 (47.8)**	72 (10.1)	156 (21.8)	146 (20.4)	**376 (52.5)**	340 (47.5)	**686 (95.8)**	14 (2.0)	13 (1.8)	3 (0.4)
2008	**1536 (42.3)**	380 (10.5)	753 (20.7)	965 (26.6)	**2083 (57.3)**	1551 (42.7)	**3502 (96.4)**	77 (2.1)	6 (0.2)	49 (1.3)	**1979 (43.6)**	529 (11.7)	909 (20.0)	1120 (24.7)	**2479 (54.6)**	2058 (45.4)	**4417 (97.4)**	70 (1.5)	31 (0.7)	19 (0.4)
2009	**1547 (43.3)**	449 (12.6)	726 (20.3)	848 (23.8)	**1929 (54.0)**	1641 (46.0)	**3444 (96.5)**	64 (1.8)	8 (0.2)	54 (1.5)	**2302 (42.9)**	610 (11.4)	1086 (20.2)	1374 (25.6)	**2907 (54.1)**	2465 (45.9)	**5227 (97.3)**	80 (1.5)	38 (0.7)	27 (0.5)
2010	**1494 (43.1)**	405 (11.7)	814 (23.5)	753 (21.7)	**1895 (54.7)**	1571 (45.3)	**3332 (96.1)**	80 (2.3)	1 (0.03)	53 (1.5)	**449 (42.8)**	130 (12.4)	225 (21.5)	244 (23.3)	**543 (51.8)**	505 (48.2)	**1021 (97.4)**	14 (1.3)	5 (0.5)	8 (0.8)
2011	**1511 (43.2)**	362 (10.3)	775 (22.1)	853 (24.4)	**1903 (54.4)**	1598 (45.6)	**3368 (96.2)**	88 (2.5)	1 (0.03)	44 (1.3)	**485 (43.0)**	112 (9.9)	231 (20.5)	300 (26.6)	**622 (55.1)**	506 (44.9)	**1111 (98.5)**	7 (0.6)	2 (0.2)	8 (0.7)
2012	**1371 (45.4)**	287 (9.5)	627 (20.8)	734 (24.3)	**1679 (55.6)**	1340 (44.4)	**2920 (96.7)**	64 (2.1)	4 (0.1)	31 (1.0)	**500 (44.1)**	87 (7.7)	222 (19.6)	324 (28.6)	**613 (54.1)**	520 (45.9)	**1113 (98.2)**	14 (1.2)	1 (0.1)	5 (0.4)
2013	**1925 (43.1)**	459 (10.3)	983 (22.0)	1099 (24.6)	**2522 (56.5)**	1944 (43.5)	**4337 (97.1)**	84 (1.9)	6 (0.1)	39 (0.9)	**622 (57.2)**	63 (5.8)	191 (17.6)	212 (19.5)	**652 (59.9)**	436 (40.1)	**1058 (97.2)**	12 (1.1)	1 (0.1)	17 (1.6)
2014	**2244 (46.8)**	526 (11.0)	1019 (21.2)	1007 (21.0)	**2610 (54.4)**	2186 (45.6)	**4559 (95.1)**	99 (2.1)	7 (0.1)	131 (2.7)	**560 (54.6)**	45 (4.4)	223 (21.7)	198 (19.3)	**554 (54.0)**	472 (46.0)	**985 (96.0)**	14 (1.4)	2 (0.2)	25 (2.4)
2015	**2435 (45.4)**	623 (11.6)	1144 (21.3)	1163 (21.7)	**2778 (51.8)**	2587 (48.2)	**5085 (94.8)**	88 (1.6)	6 (0.1)	186 (3.5)	**794 (57.6)**	97 (7.0)	217 (15.7)	270 (19.6)	**755 (54.8)**	622 (45.1)	**1226 (89.0)**	10 (0.7)	1 (0.1)	141 (10.2)

3.2 Correlation between air pollutants and meteorological

A bivariate Pearson's product-moment correlation coefficient (r) was calculated to assess the size and direction of the linear relationship between the concentration of every air pollutant and meteorological factor. Pearson's correlation coefficient between air pollutants and meteorological parameters is presented in Table 4. The average daily concentration of five pollutants and meteorological parameters showed significant positive and negative correlations. Among the contaminants that exhibit a strong correlation (>0.6) are NO_2 and CO had a significantly positive association (r =0.623, p<0.01), followed by SO_2 with CO (r =0.463, *p*<0.01). The study from [8] also offers the highest correlation between NO_2 and CO. The positive correlation may be supported by the reaction of CO entering the oxidation cycle and nitrogen monoxide (NO) being oxidized to NO_2 [8]. SO_2 showed a significantly low positive correlation with temperature (r =0.144, p<0.01). In addition, a significant negative correlation was found between temperature and relative humidity (r = -0.450, p<0.01) and relative humidity with wind speed (r = -0.139, p<0.05). The significance of the negative correlation between temperature and relative humidity means that the increase in ambient air temperature will reduce the moisture content (water vapor) in the area. A similar finding was observed in cities like Putrajaya [9]. There were also significant negative correlations between O_3 and relative humidity (r = -0.260, p<0.01). Relative humidity corresponds to the wet condition of the area. Wet conditions or high relative humidity will reduce O_3 formation because insufficient sunlight drives O_3 formation [10]. The correlation between trace gases shows significant positive correlations between primary gases such as CO, NO_2, and SO_2.

Table 4. Correlation of air pollutants and climatic parameters.

	SO_2	O_3	CO	NO_2	PM_{10}	WS	T	RH
SO_2	1							
O_3	-0.145*	1						
CO	0.463**	-0.068	1					
NO_2	0.154**	0.073	0.623**	1				
PM_{10}	0.088	0.394**	0.042	-0.028	1			
WS	-0.058	0.062	0.047	-0.085	0.070	1		
T	0.144**	-0.061	-0.058	-0.031	0.063	0.068	1	
RH	-0.013	-0.260**	0.148	0.096	-0.027	-0.139*	-0.450**	1

WS = Wind Speed, T = Temperature, RH = Relative Humidity. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 (2-tailed)

3.3 Poisson regression between air pollutants and cardio-respiratory hospitalization

Table 5 provides both the coefficient estimates (B) of the Poisson regression and the exponentiated values of the coefficient [Exp (B)]. The average from two places (Pengkalan Chepa and Kota Bharu) was used to represent the data for Kota Bharu. Poisson regression was run to predict the association of five criteria air pollutants with increased in cardio-respiratory hospitalization. The RR value has been estimated using the overall pollutant and hospitalization data.

The dependent variables of these tables are cardiovascular and respiratory diseases. The independent variable is PM_{10}, SO_2, NO_2, CO, and O_3. The five pollutions are statistically significant with cardiovascular and respiratory diseases except for CO. The RR for cardiovascular diseases shows the strongest association with O_3, SO_2, and NO_2 (4.873, 1.537, and 1.212), respectively. The highest RR estimate is O_3 (RR=4.873) (95% CI 2.768-8.578). This result was supported by [8], whereas O_3 had the highest RR in cardiovascular hospitalization [8]. According to [11], O_3 exposure in humans has been associated with increased hospital admissions related to cardiovascular complications, as O_3 mediates an inflammation response and increased oxidative stress in the cardiovascular system [11].

After that, the highest RR for respiratory is NO_2 (RR= 2.021) (95% CI 6.170, 6.620), which is different from cardiovascular. People suffering from respiratory diseases such as asthma are susceptible to NO_2 at high concentrations. According to [12], patients with asthma and chronic obstructive pulmonary disease (COPD) have been associated with an increased risk of respiratory hospitalization after exposure to NO_2 [12]. This might happen due to the traffic vehicles at Kota Bharu, which increased the concentration of NO_2.

Table 5. Relative Risk (RR) and CI for cardiovascular and respiratory hospitalization.

Model	Cardiovascular		Respiratory	
	RR	95% CI	RR	95% CI
Intercept	609.691	(594.009, 625.787)	980.682	(960.670,1001.110)
SO_2	1.537	(2.970, 7.956)	1.952	(1.013, 3.762)
NO_2	1.212	(1.156, 1.272)	2.021	(6.170, 6.620)
CO	0.040	(0.034, 0.047)	0.064	(0.056, 0.074)
O_3	4.873	(2.768, 8.578)	1.128	(4.427, 2.874)
PM_{10}	0.991	(0.990, 0.992)	1.008	(1.007, 1.008)

4 Conclusion

The air concentration of air pollutants and meteorological value can differ in different study areas. This research shows that there is a relationship between air pollutants (SO_2, NO_2, CO, O_3, PM_{10}) with meteorological parameters (wind speed, temperature, relative humidity) and air pollutants with hospitalization (cardiovascular and respiratory). A positive correlation between NO2 and CO may be supported by the reaction of CO entering the oxidation cycle and nitrogen monoxide (NO) being oxidized to NO_2. There were also negative correlations between O_3 and relative humidity. According to [10], relative humidity wet conditions or high relative humidity will reduce O_3 formation due to insufficient sunlight to drive O_3 formation. This study shows that the concentration of all pollutants during 2000-2015 in the study area is below the MAAQS.

These studies focused on a few factors, such as wind speed, temperature, and relative humidity, all of which influence air pollutants. The changes in weather patterns in Malaysia also contribute to the changes in meteorological parameter concentration, and the meteorological parameters play a role in increasing and decreasing pollutants. Air pollutants also contribute to cardiovascular and respiratory hospitalization. The most influential factors are O_3 (cardiovascular diseases) and NO_2 (respiratory diseases). The value of RR for both concentrations is higher than other pollutants and proves that the air pollutants factors can impact cardiovascular and respiratory hospitalization.

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