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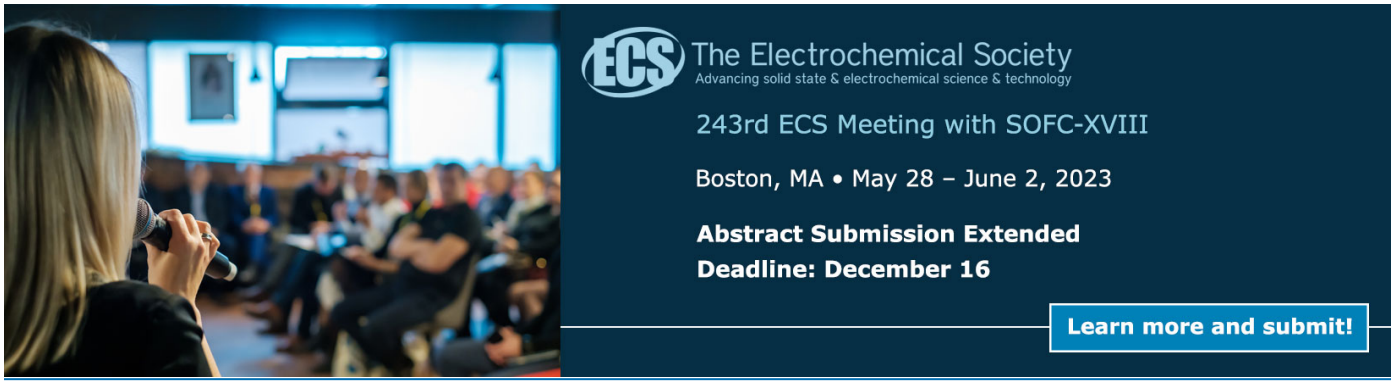


Comparison of common air pollutants, meteorological parameters, and cardio-respiratory hospitalization between urbanized areas in Kelantan

Nurul Najwa Mat Sahar[1], Siti Hajar Ya'acob[1]*, Norrimi Rosaida Awang[1], Wong Hie Ling[1] and Siti Aisyah Nawawi[1]

[1]Environmental Sustainable Science Program, Department of Natural Resources and Sustainability, Faculty of Earth Science, Universiti Malaysia Kelantan, 17600 Jeli, Malaysia
*E-mail: hajar.y@umk.edu.my

Abstract. A high concentration of air pollution is relational to meteorological conditions and the consequences can lead to health problems which are cardiovascular and respiratory-related diseases. This study aimed to compare air pollution, meteorological reading, and hospitalization in urbanized areas in Kelantan. The secondary data for this study were obtained from DOE and MOH for descriptive and trend analysis from the year 2000 until 2015 at three different locations: Tanah Merah, Pengkalan Chepa, and Kota Bharu Kelantan. The mean concentration for SO_2, O_3, CO, NO_2, and PM_{10} were 0.001 ± 0.001 μg/m^3, 0.014 ± 0.004 μg/m^3, 0.657 ± 0.145 mg/m^3, 0.007 ± 0.002 μg/m^3 and 45.195 ± 11.229 μg/m^3 respectively. Overall, the concentration of all the criteria air pollutants was lower than the MAAQS except for PM_{10}. The trend analysis shows the concentration of air pollutants, and the meteorological parameter were fluctuating and influenced by the monsoon. High wind speed and temperature were observed during the NE and SW monsoon, respectively. Tanah Merah showed a higher concentration of PM_{10} compared to the other two locations. In contrast, Kota Bharu and Pengkalan Chepa has higher gasses concentration than Tanah Merah. The gasses result in consistent with cardio and respiratory-related hospitalization which showed higher hospitalization recorded in Kota Bharu than Tanah Merah. In conclusion, the urbanized areas have different dominant air pollutants due to the potential major sources that exist differently.

1. Introduction

Air is an important element to humans and the environment. Air pollution is a combination of gasses and solid particles in the air that harm human health [1]. Nowadays, the quality of air is at stake due to the increasing population, industrial activities, agriculture, and urban development. Other causes of air pollution, range from man-made activities (burning fossil fuels, vehicle emissions, deforestation, open burning) and natural occurring pollution (volcanic eruptions, forest fires) [2, 3]. Concerning Malaysia's environment, the main air emission sources come from development activities including industries, power generation, motor vehicles, as well as land clearing, open burning, and forest fire [4].

Chemicals from factories, dust, and car emissions may be suspended as particles. The emitted air pollutants can harm human health, animals, plants, and damage buildings. Some air pollutants are poisonous and can harm human health. [5] estimates about 7 million people die annually due to exposure to fine particles in contaminated air. For example, PM_{10} exposure is very harmful to human health. According to [6], exposure to PM_{10} can affect both lungs and the heart. Whereas, breathing in ozone

(O_3) can cause chest pain, coughing, throat irritation, and congestion [6]. The level of air pollutants concentration may be depending on the variety of emission sources either from natural or human-made activities. The emission from human-made activities varies spatially that lead to a distribution of air pollutants over a geographic area [7]. Therefore, this study aims to first identify and compare the trend of criteria air pollutants, meteorological parameters, and cardio-respiratory hospitalization between the different urbanized locations.

2. Methodology

2.1. Study area

There are three different location of study area which is Pengkalan Chepa, Tanah Merah and Kota Bharu**.** The secondary data on air pollutants and hospitalization were obtained from Department of Environment (DOE) and Ministry of Health (MOH), respectively. This study focuses on secondary data monitored by 3 continuous Air Quality Monitoring (CAQM) stations, situated in Kelantan namely SK Dato Hashim 2 (Pengkalan Chepa), SMK Tanah Merah, and SMK Tanjung Chat, Kota Bharu. The measuring instruments were fully automated. The hospitalization analysis for this study is cases recorded in Hospital Tanah Merah and Hospital Raja Perempuan Zainab II, Kota Bharu, Kelantan.

(a) (b) (c)

Figure 1: Location of CAQM stations at three study areas (a) Pengkalan Chepa, (b) Tanah Merah and (c) Kota Bharu (Google, 2021)

2.2. Secondary data acquisition

Air quality secondary data were obtained from the DOE which comprises particulate matter 10 (PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3). The data is originally provided hourly for every year. The secondary data of meteorological parameters (relative humidity, temperature, and wind speed) from DOE were from the same locations. The duration of data analyzed in this study was dependent on the availability of the data for instance CAQM stations in Pengkalan Chepa and Tanah Merah were established from the year 2000 to 2008 and 2009 until recent days, respectively.

The secondary data of hospitalizations for cardiovascular and respiratory disease recorded in hospitals Tanah Merah and Kota Bharu were obtained from the MOH using National Medical Research Register (NMRR). This study uses MOH patients' data; hence obtained the ethical approval from Medical Research Ethics Committee (MREC) with ethical number NMRR-17-1940-35004. The timeframe of the hospitalization data is from the year 2000 until 2015, and the trend analysis will be yearly.

2.3. Data processing and analysis

First, the data was arranged monthly and yearly for each pollutant concentration, meteorological parameter, and patient demographic information. After that, data that has been provided were arranged which is the change over time in the same sample of the group in excel. The data that has been arranged

monthly and yearly is transferred into SPSS version 26 for statistical analysis comprising descriptive and trend analyses. The trend analysis and graphic visualization using Excel were conducted for each pollutant, meteorological parameter, and patient hospitalization information to show the trends over time (years and months).

3. Results and Discussion

3.1. Descriptive analysis of air contaminants and climatic parameters

Table 1 shows the descriptive statistic of five air pollutants and three meteorological parameters from all three locations. The N (the number of valid observations for the variables) for O_3 and CO is different from SO_2, NO_2, and PM_{10} because of the missing value in the data that might happen due to the malfunction of equipment or error in measurement. The mean concentration for (SO_2, O_3, CO, NO_2, PM_{10}) were 0.001 ± 0.001 μg/m^3, 0.014 ± 0.004 μg/m^3, 0.657 ± 0.145 mg/m^3, 0.007 ± 0.002 μg/m^3 and 45.195 ± 11.229 μg/m^3 respectively. Overall, the concentrations of the pollutants were lower than the Malaysian Ambient Air Quality Standard (MAAQS) as enforced by [8]. In this study, PM_{10} is the most dominant air pollutant in the ambient air in this area followed by CO. The high concentration of PM_{10} can be caused by functional motor vehicle sources, especially during rush hour in the city. It might happen with the high numbers of motor vehicles with slow movement during the traffic. 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. The high motor vehicle emission also can increase the concentration of CO.

Table 1. Descriptive analysis of air pollutants and climatic parameters from 2000 to 2015

	N	Min	Max	Mean	Std. Deviation
SO_2 (μg/m^3)	377	0.000	0.005	0.001	0.001
O_3 (μg/m^3)	193	0.033	0.028	0.014	0.004
CO (mg/m^3)	193	0.357	1.065	0.657	0.145
NO_2 (μg/m^3)	377	0.002	0.012	0.007	0.002
PM_{10} (μg/m^3)	377	22.764	92.234	45.195	11.229
WS (m/s)	353	3.523	8.592	5.272	.826
T (°C)	347	24.272	29.433	26.975	1.023
RH (%)	289	70.996	91.219	80.536	4.292

WS = Wind Speed, T = Temperature, RH = Relative Humidity

3.2. Monthly trends analysis of air pollutants and meteorological parameter by different location

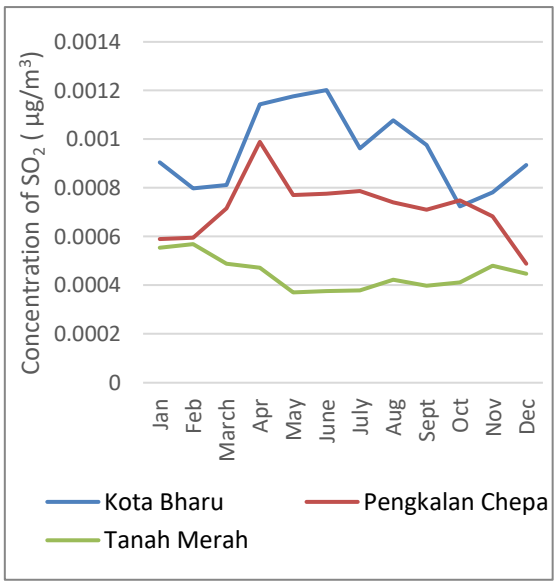
Figure 2(a) shows the level concentration of SO_2 at Kota Bharu is higher rather than Pengkalan Chepa and Tanah Merah. Kota Bharu is a city center in Kelantan which is surrounded by several activities such as industries and commercial areas that can be the main sources of SO_2 emissions in Kota Bharu. However, the concentration of SO_2 at these three locations shows that it is below the recommended MAAQS (IT-1) of 24 hours on average (105 μg/m^3). It might happen due to the improved quality of petrol (EURO-4M RON 97) which is lead to fewer vehicle emissions. The most significant change is in the reduction of Sulphur from the current level of 500 parts per million (ppm) to just 50 ppm (90% decrease) [9].

As shown in Figure 2 (b), the concentration of NO_2 at Kota Bharu was higher than Pengkalan Chepa and Tanah Merah. However, the concentration of NO_2 at Tanah Merah in January was the highest in the twelve months. According to [10], NO_2 primarily gets in the air from the open burning of fuel. A high concentration of NO_2 is due to incomplete combustion from motor vehicles. NO_2 concentration at Tanah Merah might be emitted at maximum levels when vehicles move at high speed along roads and highways. Tanah Merah was a new emerging urban area where it is now placed as the second-most

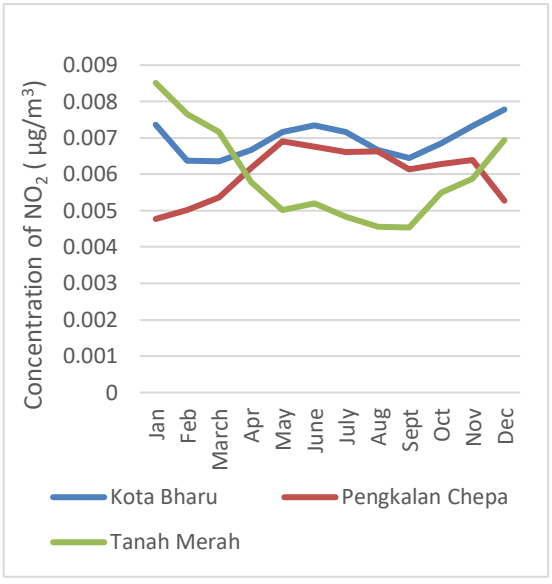
urban area in Kelantan after Kota Bharu [11]. Overall, the concentration of NO_2 was lower than the MAAQS.

Figure 2 (c) shows the highest concentration of O_3 was during January. According to [12], the major sources of O_3 production were local emission sources and anthropogenic activities emitting O_3 precursor gases. The concentration of O_3 was below the MAAQS. The data for Pengkalan Chepa and Tanah Merah is not available for O_3. Whereas Figure 1(d) shows the fluctuations of CO concentration over the month. The CO concentration during November is the highest. The increase in CO might happen due to the greatest sources of motor vehicles or machinery that burn fossil fuels due to the economic growth at Kota Bharu Kelantan [12, 13]. The high CO concentration may also have been caused by local transportation sources. The CO concentration was also far below the MAAQS level.

The average concentration of PM_{10} in all three locations was below the MAAQS. The highest concentration in this study also remains below the value proposed by MAAQG (IT-1) except for Tanah Merah from January to April. The concentration nearly at all locations exceeded the guideline when compared to MAAQG IT-2 and IT-3. In Figures 1(e) shows that, PM_{10} concentration at Tanah Merah is higher than Kota Bharu and Pengkalan Chepa. Even though Kota Bharu is the city center in Kelantan, Tanah Merah is also a developing city which is the second urban area in Kelantan after Kota Bharu [10]. The potential sources of PM_{10} are dust, industrial emissions, and construction. Industrial emissions are among the major contributor to air pollution in Malaysia [14].



(a)



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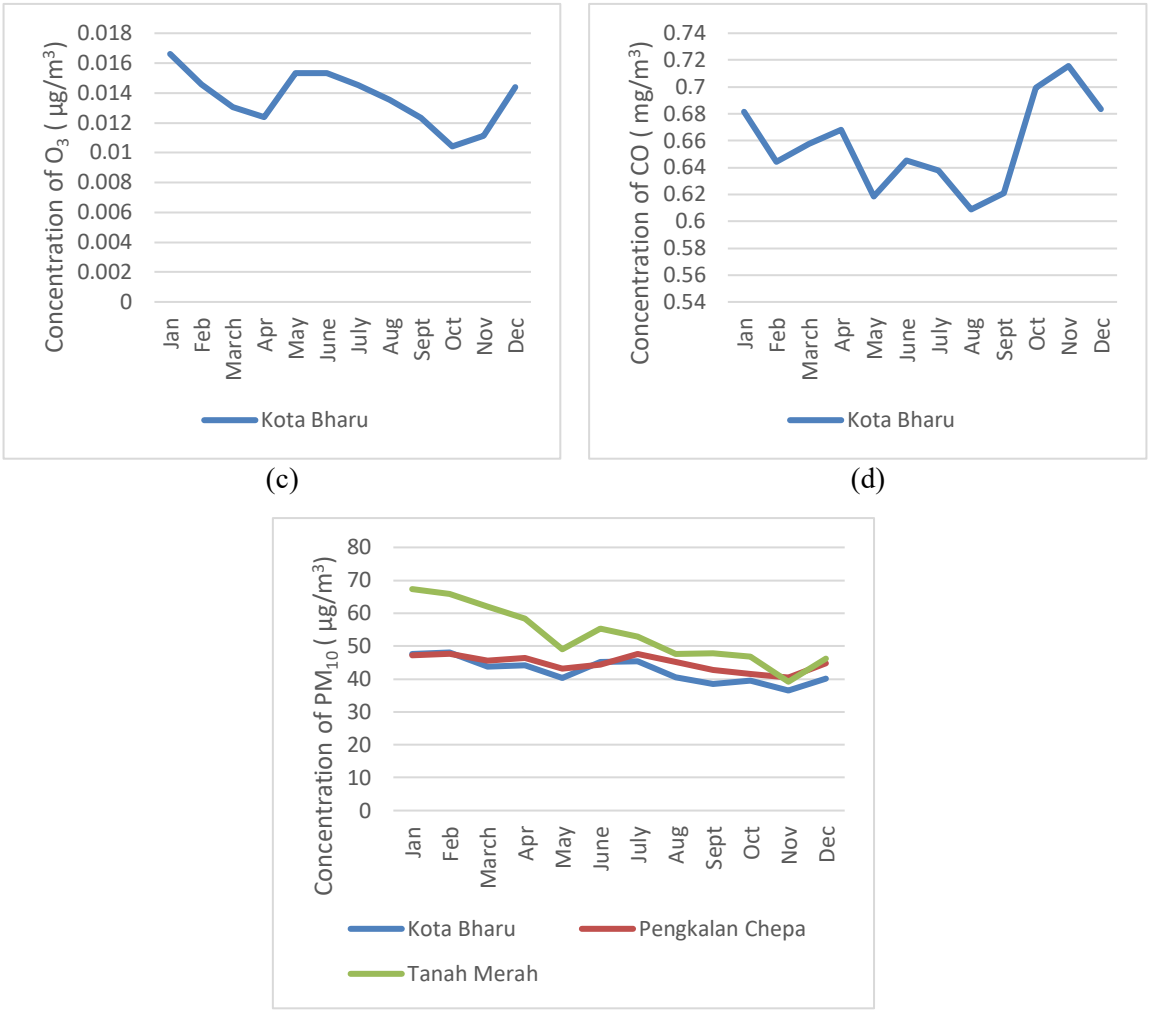


Figure 2: Monthly average concentration of SO_2 (a), NO_2 (b), O_3 (c), CO (d), and PM_{10} (e) from year 2000-2015

Figure 3(a) shows the wind speed value at Kota Bharu, Pengkalan Chepa and Tanah Merah. During Northeast Monsoon (November until March), Kota Bharu, Pengkalan Chepa and Tanah Merah show increasing trends. According to [15], wind speed during Northeast monsoon seasons can reach up to 15.4 m/s. This indicates that wind speed in the Northeast is higher than in the Southwest [15]. During the northeast monsoon, there were heavy rain and rough seas, and it can cause a flood. Kelantan is highly exposed to floods, especially during the northeast seasons. In 2014, the flood in Kelantan was unprecedented and the largest recorded flooding event in the century [16].

The Figure 3(b) shows, the value of temperature at Kota Bharu, Pengkalan Chepa and Tanah Merah. The graph shows that all three locations have a high temperature during April and May which to Southwest Monsoon. The studies from [15] showed that during the Southwest monsoon season, the air temperature on the Asian continent is high due to low pressure. The dry and hot season occurs when seasonal winds from southwest Sumatra, Indonesia blow and move towards the west coast of Peninsular Malaysia and are blocked by the Titiwangsa Mountain Range [17]. A high temperature can increase the

quantity of biomass burning and the evaporation of materials for example soil dust, from the earth's surface [18].

Figure 3(c) shows the value of relative humidity at Kota Bharu, Pengkalan Chepa, and Tanah Merah. The graph for relative humidity was a negative correlation with temperature. An increasing value of relative humidity will decrease the value of temperature. High relative humidity of the air occurs when the air temperature approaches the dew point value. Therefore, temperature directly relates to the amount of moisture the atmosphere can hold [19].

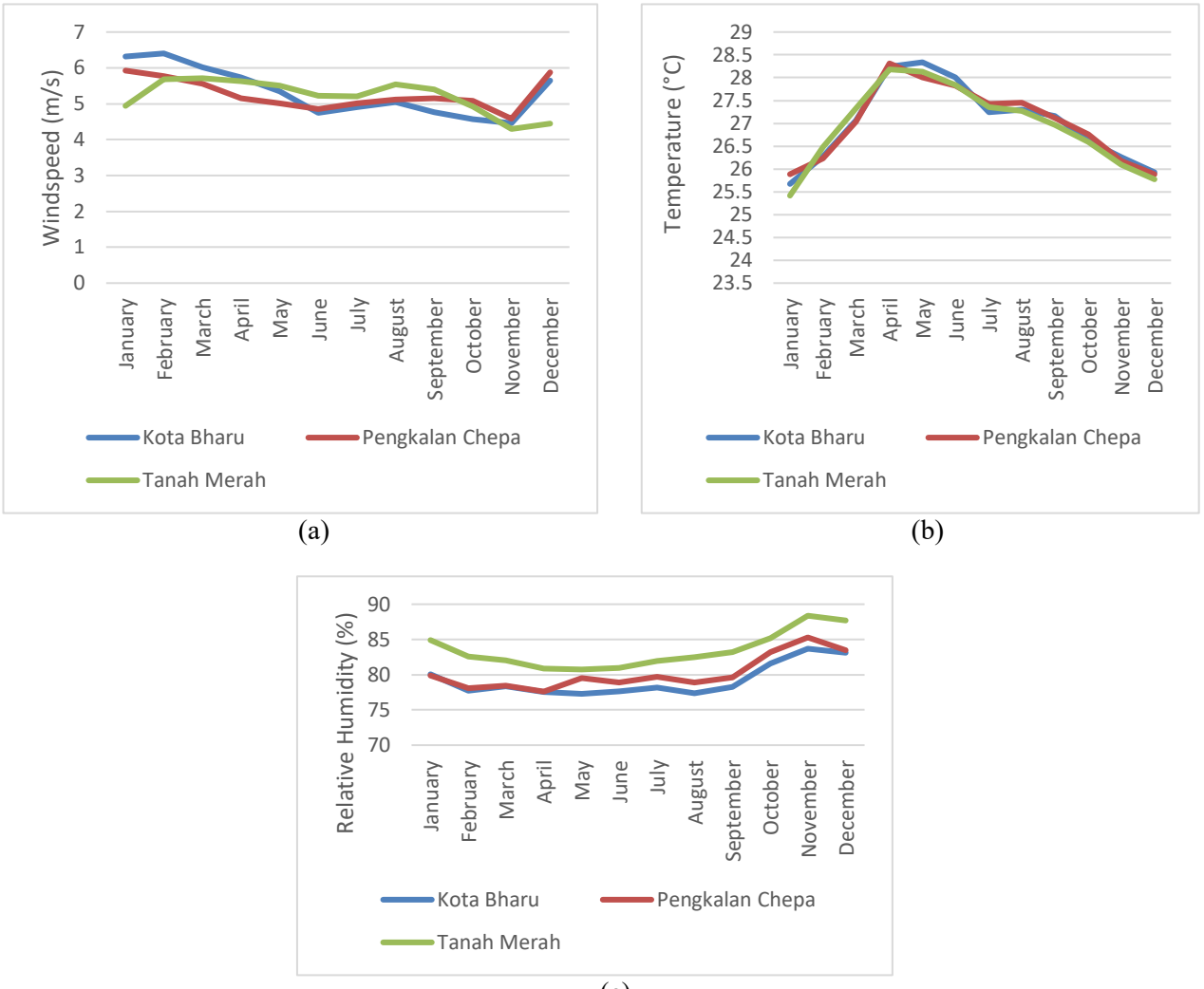
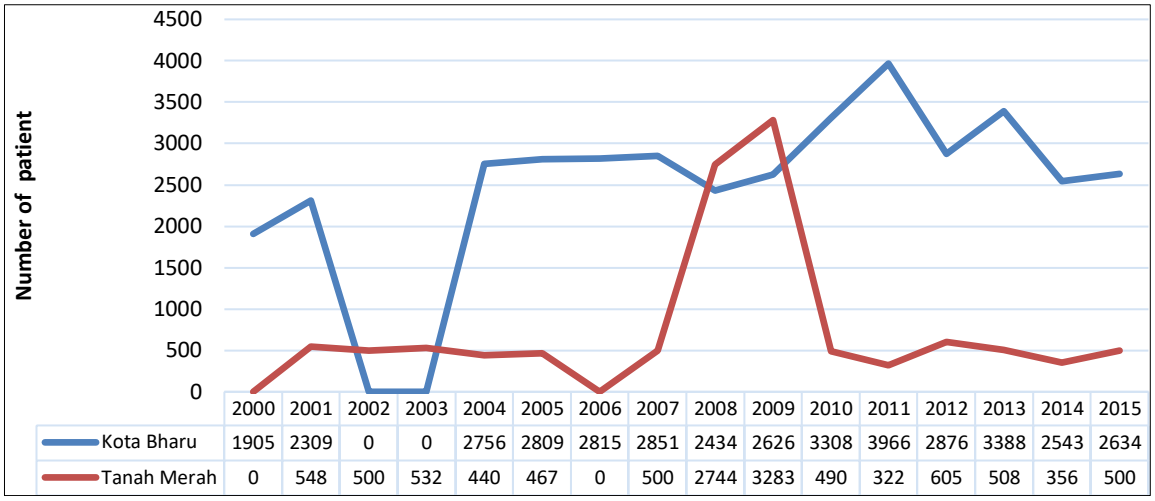


Figure 3: Monthly average value of wind speed, temperature, and RH for 2000-2015

3.3. Descriptive and trend analysis for cardiovascular and respiratory hospitalization

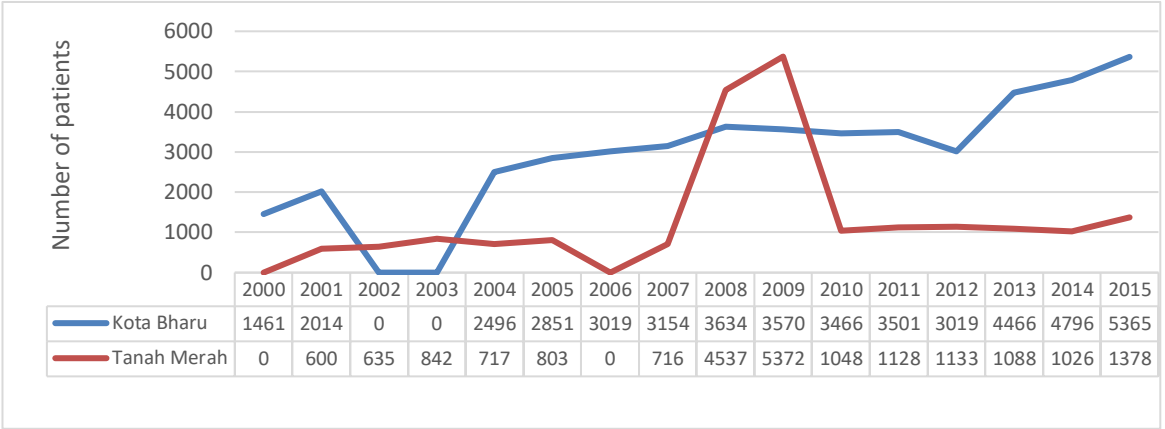
Figure 4 shows the total of patients that consist with cardiovascular and respiratory disease at the Hospital in Kota Bharu (blue line) and Tanah Merah (red line). During 2002 and 2003, the data for cardiovascular and respiratory hospitalization is not available. The highest average number of patients at Kota Bharu is during 2011. [20] stated that in 2011 the country experienced several short spells of haze episodes due to the transboundary haze pol because of fires from Central Sumatra and Kalimantan, Indonesia that occurred during the dry period from the month solution May to September 2011. These

had contributed to the slight deterioration of overall air quality in 2011 [20]. From 2007 until 2008, the graph shows a rapidly increased number of patients at Tanah Merah, and continuously increased until 2009. Figure 4(b) shows that, the total number of patients for respiratory at Hospital Kota Bharu was higher than at Tanah Merah. Tanah Merah show the highest number of patients in 2009. A previous study by [21] stated that the trend for respiratory hospitalization is highest at the end of the year (Aug-Dec) 2012 and continues to increase until January 2013 [21].



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Kota Bharu	1905	2309	0	0	2756	2809	2815	2851	2434	2626	3308	3966	2876	3388	2543	2634
Tanah Merah	0	548	500	532	440	467	0	500	2744	3283	490	322	605	508	356	500

(a)



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Kota Bharu	1461	2014	0	0	2496	2851	3019	3154	3634	3570	3466	3501	3019	4466	4796	5365
Tanah Merah	0	600	635	842	717	803	0	716	4537	5372	1048	1128	1133	1088	1026	1378

(b)

Figure 4: Yearly (a) cardiovascular and (b) respiratory related hospitalization from 2000 to 2015

4. Conclusions

This study shows that the concentration of all pollutants from 2000 to 2015 in the study area is below the MAAQS except for PM_{10}. These studies found wind speed, temperature, and relative humidity influence air pollutants concentration during the monsoon. The changes in the weather pattern in Malaysia also contribute to the changes in meteorological parameters concentration and the meteorological parameters play role in increasing and decreasing pollutants. This study found that gasses pollutants had a similar trend which all were higher in urbanized areas like Kota Bharu and Pengkalan Chepa. The cardiovascular and respiratory trend also showed high hospitalization cases in Kota Bharu compared to Tanah Merah. It is suggested to analyze the association between gasses concentration with hospitalization to confirm there is a causal relationship between air pollutants and cardiovascular and respiratory disease.

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