

Temporal analysis of air pollutants in the most affected monsoon region

Omar Kairan, Nur Nasehah Zainudin, Nurul Hasya Mohd Hanafiah, Nur Emylia Arissa Mohd Jafri, Fukayhah Fatiha@Suhami, Muhammad Firdaus Mustapha

Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Kelantan, Malaysia

Article Info

Article history:

Received Mar 20, 2021

Revised Jun 9, 2021

Accepted Jun 17, 2021

Keywords:

Air pollution
Carbon monoxide
Cluster analysis
Nitrogen dioxide
Ozone
Particulate matter 10
Sulphur dioxide
Temporal variation

ABSTRACT

Air pollution has become an issue at all rates in the world. In Malaysia, there is a system known as air quality index (AQI) used to indicate the overall air quality in the country where the air pollutants include or the new ambient air quality standard are sulphur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), ozone (O₃) and particulate matter with size less than 10 (PM₁₀). The concentration levels of the air pollutants were said to be affected by the monsoon changes. Therefore, this study is conducted to examine the existence of temporal variations of each air pollutant then identify the differences of each air pollutants concentration in temporal variations. This study uses secondary data where data that has been retrieved from the Department of Environment (DOE) where it is data of air pollution specifically for Kota Bharu, Kelantan records. Hierarchical agglomerative cluster analysis was conducted to group monthly air quality. As a conclusion, the study can conclude that the five air pollutants grouped into several different monthly clusters mostly representing the two main monsoon seasons. Mostly air pollutant varied accordingly towards the monsoon season. During the southwestern monsoon, air pollutant concentration tends to be higher compared to the northeastern monsoon with mostly due to meteorological factors.

This is an open access article under the [CC BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license.



Corresponding Author:

Omar Kairan
Department Statistics
Universiti Teknologi Mara Kota Bharu City Campus
Lembah Sireh, 15050 Kota Bharu, Kelantan
Email: omarkr@uitm.edu.my

1. INTRODUCTION

Air pollution has turned our lives into a bane. Not only in our country, it involves countries all over the world. This is a problem. Simpler speaking, at all rates worldwide air pollution is a problem. For example, a high level of air pollutants can cause health problems in the environment, including respiratory conditions, conjunctivitis and lung functions.

In general, there are many studies have been done related to the temporal variation of pollution. There are five major pollutants listed by the Department of Environment Malaysia (DOE) counted in, which are sulphur dioxide (SO₂), nitrogen dioxide (NO₂), carbon monoxide (CO), and particulate matter with a diameter of 10 microns (PM₁₀) and ground-level ozone (O₃) [1]-[4]. Apart from ozone, air pollutant concentrations are normally higher in urban areas than in rural areas. In cities, air quality (particularly concerning PM₁₀ and NO₂ concentrations) tends to be worse near busy roads, where poorer communities often live [5].

Air pollution based on temporal variations previously had been studied by many researchers. Previous research proves the temporal variability is existed in the air pollutants [6]-[10]. Temperature and sunlight affect chemical reactions in the atmosphere that cause the concentration levels of air pollutants to be increased [7]. During hot weather, the air pollutants concentration is higher compared to during cold weather [6]. In the colder months O₃ values at the monitoring site are lower and in the warmer months higher [8]. However, has stated that chemical and biophysical feedback are at high temperatures responsible for lower O₃ concentrations [9]. PM₁₀ concentrations rose sharply in the autumn for most stations and decreased during the winter in northern background and suburban stations [10].

This phenomenon also occurs in Malaysia. A study taken placed at Kuala Terengganu which analyzed hourly data from the Department of Environment (Malaysia) for the criteria pollutants (PM₁₀, CO, O₃, NO₂, and SO₂) and meteorological factors (temperature, relative humidity, wind velocities) for 10 years found that the PM₁₀, NO₂, and SO₂ concentrations during southwest monsoon (SWM) are higher [11]. CO also found significantly different based on the temporal variable. SWM recorded the highest average level of CO, followed by inter-monsoons and northeast monsoon (NEM). This result also similar to [12]. However, according to [13], No major seasonal distinctions existed over the years between SO₂, CO and NO₂ concentrations, as calculated in Tukey's multiple comparison tests. In the coastal urban area, a different study found that SO₂ and NO₂ had a negative temperature correlation over the summer and monsoon seasons except post-monsoon seasons. Furthermore, during the whole season, except post-monsoon, the PM₁₀ showed a positive correlation with temperatures. Other than that, humidity showed a positive correlation with SO₂ and a negative correlation with PM₁₀ [14].

The concentration level of PM₁₀ had become worse during the southwest monsoon. A study conducted at three testing sites in the highly populated industrial zones based on five years of observations between 2008 and 2012 found that PM₁₀ has recorded the highest air pollution during southwest monsoon especially in industrial areas [15]. The highest concentration of air pollutants during the southwest monsoon is PM₁₀ and its lower during the northeast monsoon [1]. A study on PM₁₀ at two monitoring station Larkin and Pasir Gudang found that the average concentration of PM₁₀ during southwest monsoon is the highest in both Larkin and Pasir Gudang [16].

In a study conducted by [1], O₃ distributions were observed affected by monsoonal factor. During the winter monsoon from the northeast of the Malaysian Peninsula, the Indochina and the South China Sea has brought the pollutant O₃ into a few urban areas in Malaysia affecting the highest concentration of O₃ from January to Mac. Otherwise, O₃ become lower from Julai to August [1].

The main objective of this research is to identify the temporal variation of air pollutants. Kelantan has recorded the highest reading of the air pollution index (API) at Kota Bharu city in 2019 [17]. Kelantan has been chosen as a study area in this study since the past study of air pollution in Kelantan is not focused on the temporal variations. However, there are studies about temporal variations in other states such as the study taken in Kuala Terengganu where analyzed the data of air pollutants and meteorological factors based on temporal variations which are southwest monsoon, northeast monsoon and inter-monsoon by [18]. In addition, meteorological factors in Terengganu are similar in Kelantan since these states are situated on the east coast of Malaysia. Stated by [19], Kelantan and Terengganu issued bad weather during mid-November caused by heavy rain.

2. RESEARCH METHOD

The first section describes the field of study included in the study. The second section details the data used for example the data type, and the data source and the data categories. In addition, the hierarchical agglomerative analyzes used is explained in detail in the third section.

2.1. Study area

The state of Kelantan lies at 6° 7' 38.8668" latitude and at 102° 14' 32.2332" longitude on the northeastern corner of the peninsula. The illustrated area shows the whole area of Kelantan based on Figure 1. During the year Kelantan encounters hot and rainy weather with a total of about 2500 mm of rainfall per year since Malaysia lies close to the equator. The average temperature of Kelantan is 27°C. The region of Kelantan, in particular, is encountered by two monsoon winds: The southwest monsoon between the end of May and September, and the north east monsoon between November and March [20]. In comparison with the southwest monsoon, the northeast monsoon causes more rainfall. The study selects Kota Bharu as an observation site. The town of Kota Bharu acts as the capital of Kelantan and the economy is growing rapidly. The map of Kota Bharu, Kelantan is shown in Figure 1. The area highlighted is the district of Kota Bharu. With an estimated 319,600 populations, the overall area of Kota Bharu is about 115.6 km².



Figure 1. Map of Kota Bharu, Kelantan

2.2. Data description

This study used secondary data that has been collected by the Malaysian Department of Environment (DOE) through continuous air monitoring by Alam Sekitar Sdn Bhd (ASMA). Monthly data was collected at the air pollution monitoring station located in Tanjung Chat Secondary School Kota Bharu with 6.1465° latitude and 102.2479° longitude. This secondary data is quantitative. The dataset includes air pollutants concentration of CO (ppm), NO₂ (ppm), SO₂ (ppm), O₃ (ppm) and PM₁₀ (µg/m³) are the variables for this study. It is recorded monthly from the year 2013 to 2017.

2.3. Method of data analysis

A hierarchical clustering method is utilised to cluster the monthly pollutant concentration. Boxplot comparison of clusters provided by hierarchical cluster analysis for each pollutant to indicates how the cluster is varied.

Hierarchical clustering analysis

Hierarchical clustering analysis is used to group the objects with similar characteristics into a few groups where each larger group contains a set of subgroups which are known as clusters. Two methods are commonly used in hierarchical clustering but, this research will utilize agglomerative clustering with the average group linkage method [21]. The formula to calculate this method is:

The equation of average linkage clustering as shown in (1):

$$d_{12} = \frac{1}{kl} \sum_{i=1}^k \sum_{j=1}^l d(x_i, y_j) \quad (1)$$

where:

x_1, x_2, \dots, x_k : Observation from cluster 1

y_1, y_2, \dots, y_l : Observation from cluster 2

$d_{(x,y)}$: Distance between a subject with observation vector x and a subject with observation vector y

3. RESULTS AND DISCUSSION

This study analyzes the observation mean to get the cluster of monthly mean data for each pollutant. Table 1 shows the result for descriptive analysis. Based on the descriptive analysis of 52 observations, the minimum values for variables SO₂, NO₂ and O₃ are the same which is 0.000 ppm. Meanwhile, the maximum values are all different where the maximum value for SO₂ is 0.0046 ppm, NO₂ with 0.0146 ppm and for O₃ is 0.0309 ppm. For CO and PM₁₀ variables, the minimum values recorded are 0.4413 ppm and 30.0968 µg/m³ respectively while the maximum values are 1.2513 ppm and 90.8065 µg/m³ respectively.

The mean value for the SO₂ is 0.0009 ppm. The other four pollutants which are NO₂, O₃, CO and PM₁₀ recorded mean values of 0.0106 ppm, 0.0309 ppm, 0.7354ppm and 53.8748 µg/m³ respectively. Lastly, the standard deviation for SO₂ is 0.0009 ppm while NO₂ with 0.0033 ppm value of the standard deviation. As for the pollutant O₃, the standard deviation read is 0.0104 ppm. Then, for CO and PM₁₀, these

two pollutants recorded the standard deviation of 0.1385 ppm and 14.6630 $\mu\text{g}/\text{m}^3$ respectively. Generally, the result on [11] has a bit lower average values on almost all pollutants compared to the current study although both studies situated in the region that experience the same monsoon season. According to [22], open coastal locations are often subjected to strong, even severe wind strengths. Meanwhile, [23] stated that a higher speed of wind could have caused decrease in pollutant concentration in a certain area. Therefore, the result [11] might happen because the study area located exactly on the coast which has a lower pollution concentration strongly affected by the wind speed compared to the location of the current study.

Table 1. Descriptive statistic

Variables	N	Minimum Value (ppm or $\mu\text{g}/\text{m}^3$)	Maximum Value (ppm or $\mu\text{g}/\text{m}^3$)	Mean (ppm or $\mu\text{g}/\text{m}^3$)	Standard Deviation
Sulphur Dioxide	52	0.0000	0.0046	0.0009	0.0009
Nitrogen Dioxide	52	0.0000	0.0146	0.0106	0.0033
Ozone	52	0.0000	0.0446	0.0309	0.0104
Carbon Monoxide	52	0.4413	1.2513	0.7354	0.1385
Particulate Matter 10	52	30.0968	90.8065	53.8748	14.6630

Figures 2 (a)-(e) is the cluster analysis using a dendrogram based on monthly mean concentration for each pollutant. Further analysis on the distribution of pollutant according to the cluster is depicted in Figures 3 (a)-(e). Figure 2 shows the monthly clusters of sulphur dioxide (SO_2). Based on vertical line on the dendrogram, three monthly clusters are appropriate for this air pollutant. Cluster one is clustered in January, February, August, August, October, November and December. Meanwhile, Cluster two comprises June and July and the last cluster consists of April and May. Based on Figure 3 (a), the increase in the mean of SO_2 concentration from the first cluster until the third cluster is observed. Lowest concentrations are recorded in cluster one followed by cluster two and the highest mean recorded in cluster three. According to [24], lower temperature and humidity during rainy season (Cluster 1) leading to low-rate SO_2 from the atmosphere. However, the box plot analysis could not confirm whether is there any definite significant differences between the cluster. It might be or not holding the result as found by [13], need for further analysis to confirm the differences.

The results in Figure 2 (b) show that NO_2 is possible to divide into four clusters but only two clusters are explained. Cluster one consists of January, February, March, April and November. For cluster two consists of May, July, August, September and October. Meanwhile, only June in cluster three and December in cluster four. Furthermore, Figure 3(b) shows the distribution of NO_2 concentrations according to four clusters. It can be observed that the NO_2 concentrations for the three clusters are increasing from cluster one to cluster three. However, in the fourth cluster, the mean concentration of NO_2 is declined as the lowest mean compared to the other three clusters. Therefore, the highest mean concentration of NO_2 is recorded in cluster three where it occurs in June while the lowest mean concentration of NO_2 is recorded in cluster four where it occurred in December. The increase of NO_2 concentration in the earlier to the mid-year is due to the smaller number of rainy days during the southwest monsoon compared to the northeast monsoon period. As stated by [25] the amount of the air pollutant reduction by rainfall scavenging effect can be affected by the amount, duration and intensity of rainfall. The higher the amount, duration and intensity the rainfall scavenging effect will also high. This proven in the current study when NO_2 concentration is high during the dry season (southwest monsoon) and lower during the rainy season (northeast monsoon).

Based on Figure 2 (c) above, shows that O_3 clustering is possible to be divided into four clusters. The first cluster is comprised of October and November. The second cluster includes January, February, March, April, July and August. Concerning the third cluster, May and June are the months. The last cluster consists of one month which is December. During May and June, the highest monthly average concentrations of O_3 are observed as indicated in Figure 3 (c). In [26] stated that, O_3 is a product of vehicle emissions, energy plants, boiler factories, refineries, manufacturing installations, and other chemically-responding sources. O_3 is the most likely to be harmful in urban areas during hot, sunny days, but in colder months it can reach higher concentrations as O_3 can be transported long distances by wind. As the monitoring station in Kota Bharu, an urban area of Kelantan, it is possible to conclude that even during the northeast monsoon concentrations for O_3 are slightly higher.

Dendrogram as in Figure 2 (d) is for PM_{10} concentration. It is depicting that three monthly clusters could be formed. For the first cluster, it clustered the months of January, February, March, April, May and September. Meanwhile, the months June, July and October grouped in cluster two. The last cluster consists of the months August, November and December. The concentration of PM_{10} of cluster one and two was nearly identical based on Figure 3 (d). PM_{10} concentration highest on cluster two during June, July & October

which coincided with the southwest monsoon. This event highly associated with high temperature and lower humidity during this dry season [14]. Otherwise, concentration is recorded at cluster three which may be represented as northeast monsoon.

For CO, three clusters can be observed from the dendrogram as in Figure 2 (e). The months in the first cluster are April, May, June, July, September and October. This monthly cluster could be representing the southwest monsoon period. Whereas, the northeast monsoon group represented by the third cluster (February, December & January). Meanwhile the second cluster (March, November & August) is an inter-monsoon group of clusters. Boxplot as shown in Figure 3 (e), a decreasing pattern is from the first cluster to the third cluster is detected. Therefore, the monsoonal effect on the concentration of CO is possible since there is a different concentration between southwest monsoon and northeast monsoon. According to [27], [28], incomplete combustion of fossil fuels and the combustion of biomass is the main sources of CO. However, due to the considerable depositing phenomena during the northeast monsoon, hydroxyl groups function as sinks for removing CO from the atmosphere [28], [29].

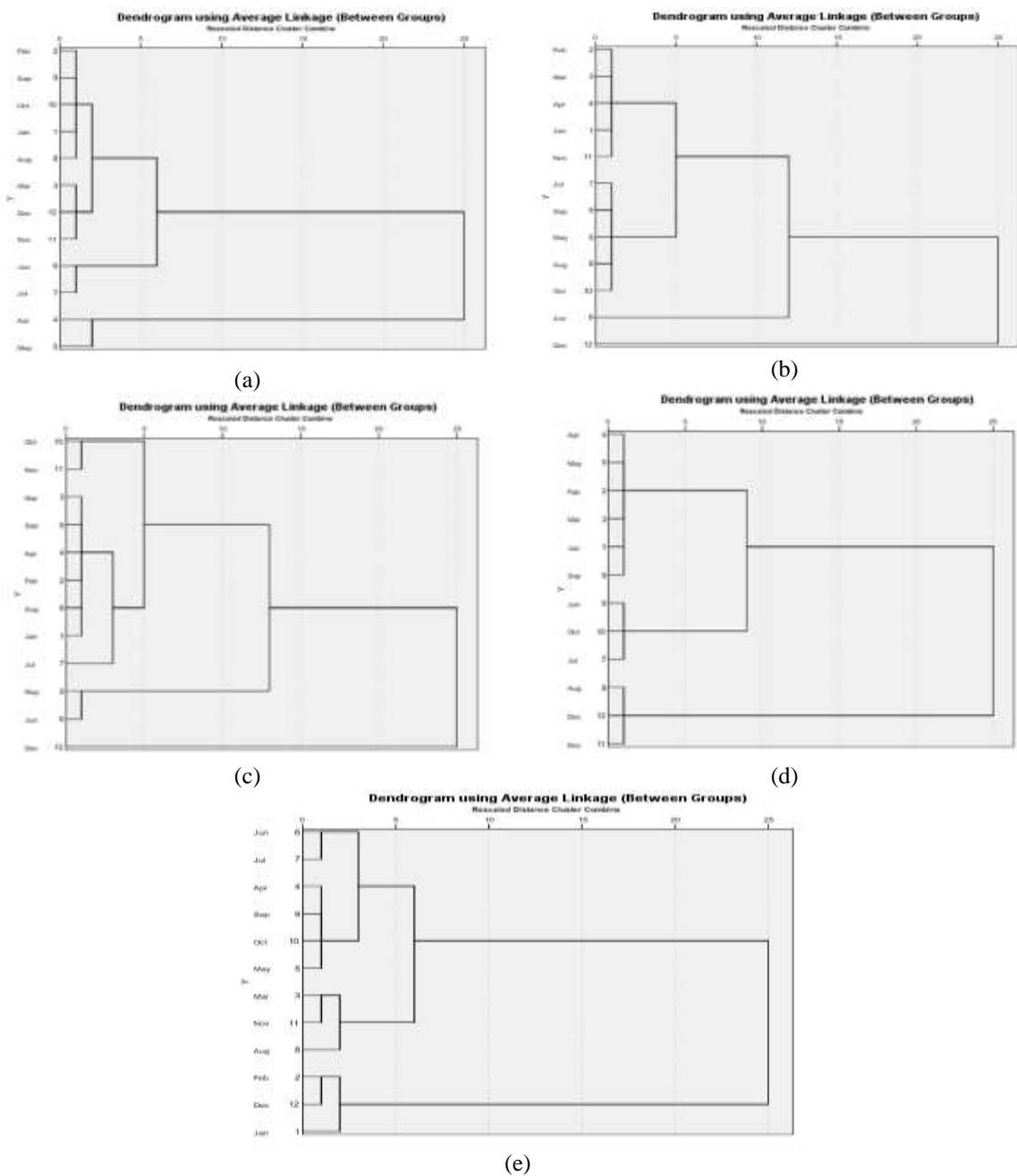


Figure 2. Monthly clustering; (a) SO₂, (b) NO₂, (c) O₃, (d) PM₁₀, and (e) CO

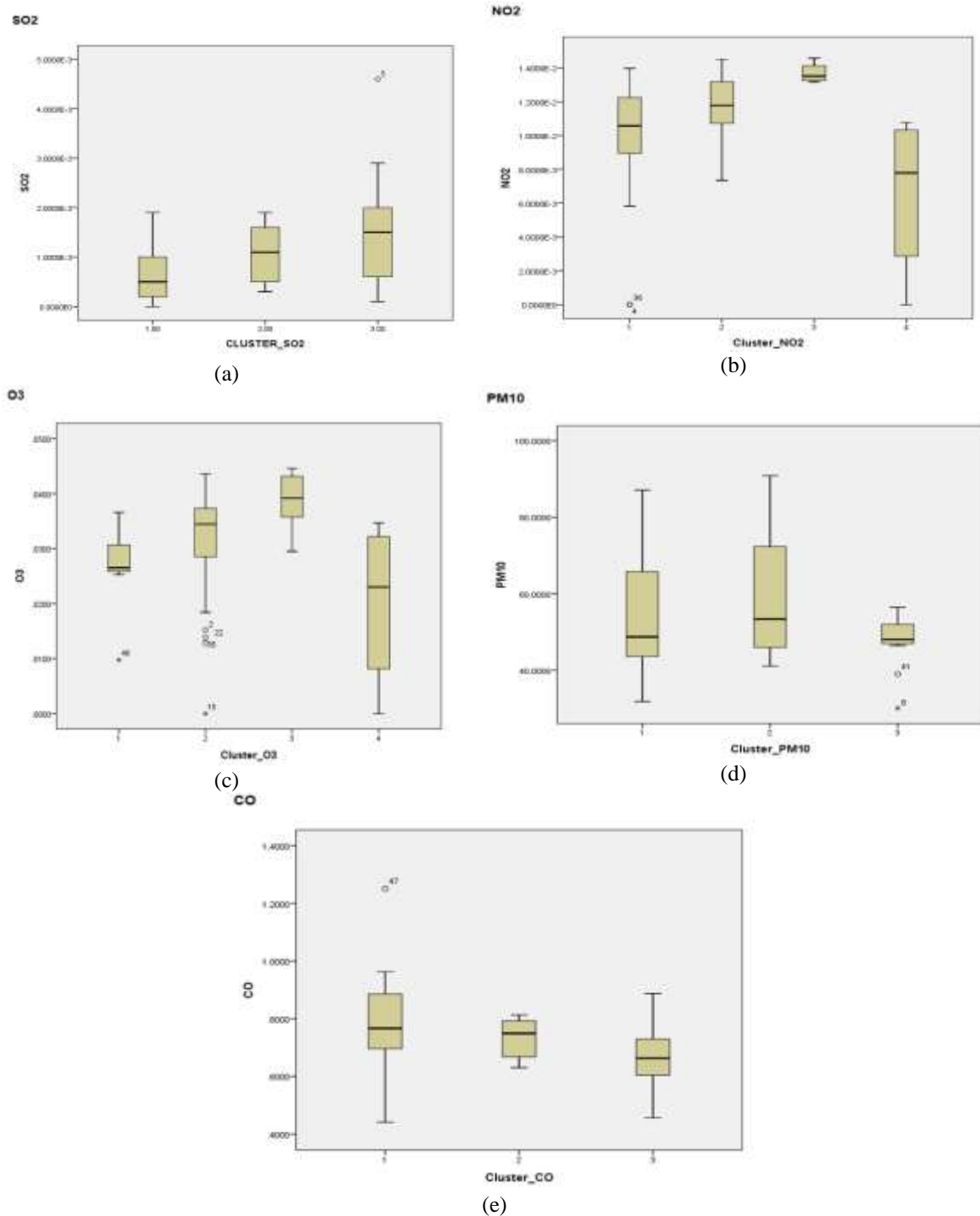


Figure 3. Boxplot based on cluster; (a) SO₂, (b) NO₂, (c) O₃, (d) PM₁₀, and (e) CO

4. CONCLUSION

The result from this study shows that there is the existence of temporal variations of air pollutants. Generally, most of the cluster formed for each pollutant has a strong relationship to three seasonal monsoons which are southwest monsoon, northeast monsoon and inter-monsoon. From the monthly variation, it shows that the mean for SO₂ concentration recorded the highest reading in months April and May which is during inter-monsoon as previously proven that there is a positive relationship between temperature and concentration in SO₂. The highest mean concentration of NO₂ was recorded during a high-temperature period which during SWM similar to what had been observed in previous study. The highest monthly

average of O₃ concentration recorded during May and June which is during the SWM. This paper also supports the previous study where the period of SWM is the period of the emissions from vehicles, power stations, factory boilers, refineries, manufacturing facilities and other sources that easily react chemically to the sun. The highest concentrations of PM₁₀ can be seen during June to October which coincides with the southwest monsoon where it experiences a dry season all over the region in peninsular Malaysia. The concentration level of CO is the highest during the southwest monsoon. The above investigation of variations in CO, NO₂, SO₂, O₃ and PM₁₀ concentrations in different monthly cluster in Kota Bharu, Kelantan shows that the mean of air pollution concentration in this large urbanized city depends on meteorological factors. One of the main factors that caused the high concentration is mainly related to the seasonal monsoon.

ACKNOWLEDGEMENTS

This paper and the research behind it would not have been possible without the exceptional support of Universiti Teknologi Mara Kota Bharu Campus for the facilities provided for the completion of the study. A thousand appreciation to the Department of Environmental Malaysia (DOE) for providing environmental data.

REFERENCES

- [1] Mohtar, A. A. A., *et al.*, "Variation of major air pollutants in different seasonal conditions in an urban environment in Malaysia," *Geoscience Letters*, vol. 5, no. 1, p. 21, 2018, doi: 10.1186/s40562-018-0122-y.
- [2] Mabahwi, N. A., Leh, O. L. H., & Omar, D., "Urban Air Quality and Human Health Effects in Selangor, Malaysia," *Procedia - Social and Behavioral Sciences*, vol. 170, 282-291, 2015, doi: 10.1016/j.sbspro.2015.01.038.
- [3] Latif, M. T., *et al.*, "The impact of urban growth on regional air quality surrounding the Langat River Basin, Malaysia," *The Environmentalist*, vol. 31, no. 3, pp. 315-324, 2011, doi: 10.1007/s10669-011-9340-y.
- [4] Azmi, S. Z., Latif, M. T., Ismail, A. S., Juneng, L., & Jemain, A. A., "Trend and status of air quality at three different monitoring stations in the Klang Valley, Malaysia," *Air Quality, Atmosphere & Health*, vol. 3, no. 1, pp. 53-64, 2009, doi: 10.1007/s11869-009-0051-1.
- [5] Department for Environment Food & Rural Affairs. Public Health: Sources and Effects of PM_{2.5}, 2020, <https://laqm.defra.gov.uk/public-health/pm25.html>
- [6] Yousefian, F., Faridi, S., Azimi, F. *et al.*, "Temporal variations of ambient air pollutants and meteorological influences on their concentrations in Tehran during 2012–2017," *Sci Rep*, vol. 10, no. 1, pp. 1-11, 2020, doi: 10.1038/s41598-019-56578-6.
- [7] Jang E., Do W., Park G., Kim M. & Yoo E. "Spatial and temporal variations of urban air pollutants and their concentrations in relation to meteorological conditions at four sites in Busan, South Korea," *Atmos Pollut Res*, vol. 8, no. 1, pp. 89-100, 2016, doi: 10.1016/j.apr.2016.07.009.
- [8] Munir, S., T.M.H., A.M.F.M., E.M., A.H.A.A., A.R.S., & I.H., "An Analysis into the Temporal Variations of Ground Level Ozone in the Arid Climate of Makkah applying k-means Algorithms," *Thai Society of Higher Education Institutes on Environment*, vol. 8, no. 1, pp. 53-60, 2015, doi: 10.14456/ea.2015.7.
- [9] Steiner, A. L., Davis, A. J., Sillman, S., Owen, R. C., Michalak, A. M., & Fiore, A. M., "Observed suppression of ozone formation at extremely high temperatures due to chemical and biophysical feedbacks," *Proceedings of the National Academy of Sciences*, vol. 107, no. 46, pp. 19685-19690, 2010, doi: 10.1073/pnas.1008336107.
- [10] Chen, W., Yan, L., & Zhao, H., "Seasonal Variations of Atmospheric Pollution and Air Quality in Beijing," *Atmosphere*, vol. 6, no. 11, pp. 1753-1770, 2015, doi: 10.3390/atmos6111753.
- [11] Fong, S. Y., Marzuki Ismail & Samsuri Abdullah., "Seasonal Variation of Criteria Pollutant in an Urban Coastal Environment: Kuala Terengganu," *MATEC Web of Conferences*, vol. 87, p. 03011, 2017, doi: 10.1051/mateconf/20178703011.
- [12] Wong, Y.-K., Mohamed Noor, N., & Mohamad Hashim, N. I., "Temporal Variation of Ambient PM₁₀ Concentration within an Urban-Industrial Environment," *E3S Web of Conferences*, vol. 34, p. 02002, 2018, doi: 10.1051/e3sconf/20183402002.
- [13] Kayes, Imrul, Shahriar, Shihab A., Hasan, Kamrul, Akhter, Momotaj & Kabir, Mohammad, Salam, Mohammed., "The relationships between meteorological parameters and air pollutants in an urban environment," *Global Journal of Environmental Science and Management*, vol. 5, pp. 265-278, 2019, doi: 10.22034/gjesm.2019.03.01.
- [14] Jayamurugan, R., Kumaravel, B., Palanivelraja, S. and Chockalingam, M.P., "Influence of Temperature, Relative Humidity and Seasonal Variability on Ambient Air Quality in a Coastal Urban Area," *International Journal of Atmospheric Sciences*, 2013, pp. 1-7, doi: 10.1155/2013/264046.
- [15] Mohd Zizi, N. A., Mohamed Noor, N., Izzah Mohamad Hashim, N., & Yusuf, S. Y., "Spatial and Temporal Characteristics of Air Pollutants Concentrations in Industrial Area in Malaysia," *IOP Conference Series: Materials Science and Engineering*, vol. 374, p. 012094, 2018, doi: 10.1088/1757-899X/374/1/012094.
- [16] Abdul Hamid, H., Hanafi Rahmat, M., & Aisyah Sapani, S., "The classification of PM₁₀ concentrations in Johor Based on Seasonal Monsoons," *IOP Conference Series: Earth and Environmental Science*, vol. 140, p. 012028, 2018, doi: 10.1088/1755-1315/140/1/012028.
- [17] Abdullah, S. M. "Two stations in Kelantan record unhealthy API readings," *NST Online*, 2019, <https://www.nst.com.my/news/nation/2019/09/523784/two-stations-kelantan-record-unhealthy-api-readings>

- [18] Fong, S. Y., Marzuki Ismail & Samsuri Abdullah, "Seasonal Variation of Criteria Pollutant in an Urban Coastal Environment: Kuala Terengganu," *MATEC Web of Conferences*, vol. 87, p. 03011, 2017, doi: 10.1051/mateconf/20178703011.
- [19] Nazari, T. "MetMalaysia: Orange-Level Weather Warning for Kelantan And Terengganu Today," 2021, <https://www.therakyatpost.com/2020/12/03/metmalaysia-orange-level-weather-warning-for-kelantan-and-terengganu-today/>
- [20] Alias, N. E., Mohamad, H., Chin, W. Y., & Yusop, Z. "Rainfall analysis of the Kelantan big yellow flood 2014," *Jurnal Teknologi*, vol. 78, pp. 9-4, 2016, doi: 10.11113/jt.v78.9701.
- [21] Johnson, R. A., & Wichern, D. W. "Applied multivariate statistical analysis," *Upper Saddle River, NJ: Prentice hall*, vol. 5, no. 8, 2002.
- [22] Steyn, D. G. "Air pollution in coastal cities," In *Air Pollution Modeling and its Application XI*, Springer, Boston, MA, pp. 505-518, 1996, doi: 10.1007/978-1-4615-5841-5_53.
- [23] Kim, K. H., Lee, S. B., Woo, D., & Bae, G. N. "Influence of wind direction and speed on the transport of particle-bound PAHs in a roadway environment," *Atmospheric Pollution Research*, vol. 6, no. 6, 1024-1034, 2015, doi: 10.1016/j.apr.2015.05.007.
- [24] Bralić, M., Buljac, M., Periš, N., Buzuk, M., Dabić, P., & Brinić, S. "Monthly and seasonal variations of NO₂, SO₂ and black-smoke located within the sport district in urban area, city of Split, Croatia," *Croatica chemica acta*, vol. 85, no. 2, pp. 139-145, 2012, doi: 10.5562/cca1966.
- [25] Kim, S., Hong, K. H., Jun, H., Park, Y. J., Park, M., & Sunwoo, Y., "Effect of precipitation on air pollutant concentration in Seoul, Korea," *Asian Journal of Atmospheric Environment*, vol. 8, no. 4, pp. 202-211, 2014, doi: 10.5572/ajae.2014.8.4.202.
- [26] Ground-level Ozone Basics. US EPA. <https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics>, 2021.
- [27] K. Park and T. S. Rhee, "Source characterization of carbon monoxide and ozone over the Northwestern Pacific in summer 2012," *Atmos. Environ*, vol. 111, pp. 151-160, 2015, doi: 10.1016/j.atmosenv.2015.04.015.
- [28] T. Holloway, H. Levy II, and P. Kasibhatla, "Global Distribution of CO. J. Geophy," *Res.* vol. 105, no. 10, pp. 123-147, 2000.
- [29] J. M. Wallace and P. V. Hobbs, "Atmospheric Science: An Introductory Survey," vol. 92, 2006.