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Assessing short term air quality trend in Malaysia based on air pollution index (APi)

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Abstract. Air Pollution Index (API) is used in Malaysia to determine the daily air quality status, which is calculated based on the daily concentrations of particulate matter (PM10), ground-level ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). This study presents short-term air quality trends based on API from the 52 air quality monitoring stations nationwide between 2010 and 2016. The air quality data and meteorological conditions were obtained from the Department of Environment and used for the API calculation. The API value is classified into six categories, namely: Good (0-50), Moderate (51-100), Unhealthy (101-200), Very Unhealthy (201-300), Hazardous (301-500), and Emergency (above 500). The coefficient of variation (CV) and Mann-Kendall trend test (MK) were used to assess the API variation and trend in each air quality monitoring station. Between the study periods, the API values were largely varied. Observation at 32 air quality monitoring stations have shown significant but small increasing trends, while 12 stations showed significant decreasing trends, and the remaining 8 stations showed no significant trends. The frequency of exceedance (API>50) was used to assess the percentages of unhealthy days. The analysis has found that air quality in Klang Valley was experiencing the highest number of unhealthy days, while the two Malaysian states in Borneo (Sabah and Sarawak) to be relatively less polluted.

1. Introduction

Air pollution is one of the global major environmental problems where it is possible to bring adverse effects to not only human, but may also to vegetation and animals. As air pollution becomes increasingly a concern since the past decades, a number of tools have been established to assist the air quality management. This includes the amendment of Environmental Quality Act (EQA) 1974 by the establishment of Air Pollution Index (API) [1]. Generally, many countries across the world have used a set of index to indicate the pollution level of atmosphere above the nation. The index is slightly different depending on the index used by the country but every index held the same purposes. Among some Southeast Asia countries, Singapore used Pollutant Standards Index (PSI), Vietnam, Thailand and Taiwan used Air Quality Index (AQI) while Malaysia used Air Pollution Index (API) [2].

In general, each of the index systems is a set of different air quality classes to indicate the air quality statues of any particular area [3]. It is normally used to report the hourly or daily air quality status which is how good or unhealthy the air is on a recent period [4]. These air quality statues are usually accessible in various websites, either through the official website of the government or even an organizational website. In addition, it is also used to communicate to the public regarding the health effects an individual could be exposed to it [5]. With this, the community could make a decision considering the health of the society and take a precaution before going out for work, school or any regular activities.

In Malaysia, Air Pollutant Index (API) was established in Malaysia since 1996 is used as one of the air quality management tools and to strengthening the air quality management in Malaysia [6]. It is used as a tool to inform both the decision makers and the general public on the subject of ambient air quality status that ranging from good to hazardous [7]. However, it was mostly used as simply the immediate announcements for the public. The calculate Air Pollution Index (API) mostly used for immediate announcement of air quality status but seldom or none at all been used as the main tool in air quality management [8]. In the absence of long-term trend analysis of air pollution index in Malaysia, it has created a wide gap of uncertainty on overall air quality in Malaysia. Therefore, this research was performed to maximize the usage of API especially in filling up the uncertainty gap on overall air quality in Malaysia, in the efforts to minimize air pollution and deem to maximize the efficiency.

2. Methodology

For this research, Malaysia is chosen as the area of study. Among all the 13 states and three federal territories in this country, the air quality status for each may varies depending on the meteorological factors and air quality parameters such as wind power and pattern, humidity, rainfall intensity on a particular time. Thus, the data from every air monitoring station in each states were used to analyze the air quality status for a particular conditions. But for a better comparison, the air quality was compared by regions. The monitoring stations are divided into six regions which involves Klang Valley, Northern Region, Southern Region, East Coast, Sarawak and Sabah.

Plus, this research includes the Air Pollution Index (API) calculation which involving five major pollutants namely as carbon monoxide (CO), ground-level ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and particulate matter (PM_{10}). Air pollution index data for a period of 7 years (2010 – 2016) were used in the study, obtained from the Department of Environment (DOE) Malaysia and Alam Sekitar Malaysia Sdn Bhd (ASMA) for the data management. In order to analyze the long-term trend of air pollution index in Malaysia, coefficient variation and Mann-Kendall trend test were used. The pollution hotspots in Malaysia were identified by using the frequency of exceedance for which values has exceeded the threshold of 50 (API > 50).

The API calculation involved the calculation of average concentration levels of the five major air pollutants with the averaging time for each pollutant was according to the Recommended Malaysian Air Quality Guideline (RMAQG) where PM_{10} and SO_2 hourly value were averaged over a 24-hour running period, CO was averaged over an eight-hour period, O_3 and NO_2 were read hourly [9]. Next, the specific sub-index value for each of the five air pollutants was determined using either the respective standard sub-index formula or the conversion table. After that, the highest sub-index value among all of the five sub-indexes was selected as the API value for the specified time period of a particular area. Lastly, the calculated API values were categorized into different air quality statuses based on the ranges for each class of API. The API was classified as either Good (0–50), Moderate (51–100), Unhealthy (101–200), Very Unhealthy (201–300), Hazardous (301–500) or Emergency (>500).

3. Results & discussions

Overall, the findings show that 32 monitoring stations have significant varied increasing trend mainly from Malaysia's Northern Peninsular Region with total average of coefficient variation, cv of 37.055±5.066%, p-value of 0.020±0.006, Kendall's value of 0.171±0.115 and Sarawak Region with value cv of 47.484±13.075%, p-value of 0.034±0.009, Kendall's value of 0.086±0.070; meanwhile 12 monitoring stations with significant decreasing trends from Malaysia's Southern Peninsular Region (cv 35.999±3.818%, p-value of 0.000±0.000, Kendall's 0.024±0.006), East Coast Peninsular Region (cv 36.384±5.575%, p-value of 0.000±0.000, Kendall's -0.288±0.002) and Sabah Region (cv 32.203±1.570%, p-value of 0.006±0.001, Kendall's -0.054±0.130); and another remaining 8-stations with non-significant trend found mainly from Klang Valley Region (cv 37.388±3.755%, p-value of 0.170±0.032, Kendall's -0.040±0.009). Whilst, the Mann-Kendall Trend Test (MK) and Coefficient

Variation (CV) for each various monitoring stations in the studied Regions is shown in Table 1 with diurnal variations of API in each stations along with the trend slope analysis. From the coefficient variation, CV analyses, the API for Klang Valley Region is identified to be varied at the range of 31.18% to 44.09% which indicates that the API values in this region are largely scattered around the mean, and the Klang stations recorded has the highest API at this region. It also shows that all of the stations in Klang Valley have significant trends except for Klang, Petaling Jaya and Shah Alam where these three stations showed no significant trends. Kuala Selangor and Cheras have decreasing trends while Putrajaya, Batu Muda and Banting have increasing trends. In addition, from there it shown that overall the air quality in Putrajaya, Batu Muda and Banting are getting worse and there are no changes in Klang, Petaling Jaya and Shah Alam while in Kuala Selangor and Cheras, the air quality is getting better in 2010 to 2016. Meanwhile, for the Northern Peninsular Region, the highest daily maximum mean of API recorded in Seri Manjung with 269.54 and followed by Seberang Jaya with 240.28 respectively. Both of these maximum daily means are in Very Unhealthy status (API: 201-300), while Langkawi has showed the lowest value of overall API mean with 34.70. Based from Table 1, it also shows that the API values in the region of Northern Peninsular are seen to have spatially varied in between 29.40% to 44.46%. In addition, positive significant trend can be seen in the majority of the stations in this region with the exception of Perai which has a negative significant trend, and Seri Manjung which have no significant trend throughout the period of study. Hence, it can be concluded that the air quality in most of the monitoring stations in Northern Peninsular are getting worse especially Sungai Petani since it has the highest increasing slope recorded in this region and also in Malaysia.

Table 1. Mann-Kendall Trend Test (MK) and Coefficient Variation (CV-%) analysis for the Air Pollution Index (API) for the year 2010 to 2016 in each monitoring stations at the six studied Regions which involves (a) Klang Valley; (b) Northern Region; (c) Southern Region; (d) East Coast; (e) Sarawak; and (f) Sabah.

Station	**Min**	**Max**	**μ**	**σ**	**CV (%)**	**p-value (α=0.05)**	**Kendall**	**Significant Trend**
Klang	0.45	450.12	55.62	20.35	36.59	0.123	0.021	No
Petaling Jaya	11.44	195.53	46.35	16.29	35.15	0.243	0.015	No
Shah Alam	0.47	248.40	46.68	18.30	39.20	0.989	0.000	No
Kuala Selangor	0.34	214.75	40.36	17.80	44.09	< 0.0001	-0.081	Negative
Putrajaya	2.13	195.73	42.60	16.75	39.32	< 0.0001	0.199	Positive
Cheras	3.38	163.94	47.76	14.89	31.18	0.001	-0.043	Negative
Batu Muda	9.90	196.19	44.39	17.58	39.61	0.001	0.046	Positive
Banting	0.36	264.46	50.99	17.32	33.96	< 0.0001	0.166	Positive
Perai	9.13	183.67	39.64	13.57	34.24	0.000	-0.051	Negative
Ipoh	2.04	163.61	42.75	12.69	29.67	< 0.0001	0.174	Positive
Seberang Jaya	8.46	240.28	48.32	14.21	29.40	< 0.0001	0.121	Positive
Sungai Petani	8.58	226.63	47.37	16.20	34.19	< 0.0001	0.382	Positive
Taiping	4.68	149.39	40.31	16.41	40.72	< 0.0001	0.175	Positive
Langkawi	1.19	222.51	34.70	14.03	40.43	< 0.0001	0.266	Positive
Kangar	1.62	221.43	36.82	13.77	37.41	< 0.0001	0.080	Positive
Minden	7.02	195.92	39.88	14.81	37.12	< 0.0001	0.342	Positive
Alor Setar	0.65	220.79	37.75	15.24	42.62	< 0.0001	0.273	Positive
Seri Manjung	0.39	269.54	39.49	17.56	44.46	0.243	0.016	No

Tanjung Malim	0.13	166.09	34.71	14.94	43.03	0.000	0.049	Positive
Pegoh	1.62	173.25	44.96	14.11	31.37	< 0.0001	0.119	Positive
Pasir Gudang	12.40	265.38	46.78	15.31	32.72	< 0.0001	0.085	Positive
Bukit Rambai	12.16	396.84	52.96	17.05	32.18	< 0.0001	-0.058	Negative
Nilai	0.06	215.48	43.37	15.78	36.37	0.700	0.005	No
Larkin	3.17	187.13	42.12	14.28	33.90	< 0.0001	0.154	Positive
Melaka	0.07	351.27	42.54	18.24	42.89	< 0.0001	0.123	Positive
Muar	5.89	329.67	42.58	16.99	39.90	< 0.0001	-0.120	Negative
Seremban	6.31	178.58	42.64	15.88	37.24	0.001	0.044	Positive
Port Dickson	0.33	266.85	45.80	15.19	33.16	< 0.0001	-0.061	Negative
Kota Tinggi	6.80	263.73	43.16	13.66	31.65	0.836	0.003	No
Kemaman	2.79	214.93	45.49	15.11	33.23	< 0.0001	0.236	Positive
Jerantut	0.99	160.52	31.52	14.93	47.36	< 0.0001	0.063	Positive
Kuantan	2.96	148.10	36.70	12.47	33.98	< 0.0001	0.103	Positive
Balok Baru	0.40	174.13	45.34	15.82	34.89	< 0.0001	-0.252	Negative
Kota Bharu	0.43	119.66	41.47	14.30	34.49	< 0.0001	0.140	Positive
Paka	0.14	149.13	34.09	14.94	43.82	< 0.0001	0.151	Positive
Kuala Terengganu	1.84	114.20	42.42	12.66	29.84	< 0.0001	-0.170	Negative
Tanah Merah	0.73	119.35	45.20	15.13	33.46	< 0.0001	-0.288	Negative
Kuching	2.17	187.28	34.39	15.94	46.35	< 0.0001	0.180	Positive
Sibu	4.74	209.16	35.14	13.74	39.01	0.006	0.036	Positive
Bintulu	2.11	98.51	37.90	14.51	38.30	0.001	0.043	Positive
Miri	1.07	130.96	29.88	13.42	44.92	< 0.0001	0.245	Positive
Sarikei	0.26	139.49	37.12	12.96	34.91	< 0.0001	0.053	Positive
Limbang	0.05	82.08	26.01	10.49	40.34	< 0.0001	0.104	Positive
Kota Samarahan	0.07	169.94	31.88	16.56	51.94	0.312	-0.014	No
Sri Aman	0.00	181.76	31.68	16.52	52.17	< 0.0001	0.067	Positive
Kapit	0.12	120.84	29.08	12.69	43.64	0.023	0.031	Positive
Permyjaya	0.38	386.83	26.72	22.25	83.26	< 0.0001	0.086	Positive
Kota Kinabalu	1.77	84.07	33.13	11.01	33.24	< 0.0001	0.147	Positive
Tawau	1.34	152.53	31.25	9.92	31.73	< 0.0001	-0.138	Negative
Keningau	0.34	94.52	29.12	10.50	36.06	0.471	-0.010	No
Sandakan	0.27	75.13	29.28	8.75	29.87	0.024	-0.030	Negative
Labuan	0.77	94.44	31.73	10.78	33.97	< 0.0001	-0.195	Negative

For Southern Peninsular Region, the highest daily maximum mean of API is recorded in Bukit Rambai with 396.84 and followed by Melaka with 351.27. These maximum daily means are categorized in the Hazardous class (API: 301-500) for the region's air quality. For the total overall mean, Bukit Rambai has shown the largest value of API with 52.96 while the smallest value is recorded in Larkin with 42.12. The daily API values in this region have spatially varied around 31.65% to 42.89%. The trends shown in this region are diverse, where there are four monitoring stations (Pasir Gudang, Larkin, Melaka & Seremban) with increasing significant trends, three stations (Bukit Rambai, Muar & Port Dickson) with decreasing significant trends and two stations (Nilai & Kota Tinggi) with no significant trends. Larkin showed the highest slope which indicate that this area has experienced the worst degradation of air quality among the monitoring stations in Southern Peninsular Region. In the East Coast Region, it is shown that Kemaman has the highest daily maximum mean of API with 214.93 which fell into Very Unhealthy status (API: 201-300). The second largest daily maximum mean was recorded in Balok Baru with 174.13 which fell into Unhealthy (API: 101-200). Moreover, these two stations have also recorded with the highest overall API means of 45.49 and 45.34 respectively. In contrast, Jerantut is recorded with the lowest overall API mean at 31.52. The diurnal API in this region can be seen at the range 29.84% to 47.36% level of variation, with all of the monitoring stations showing the significant trends where Balok Baru, Kuala Terengganu and Tanah Merah with negative slopes. Meanwhile, the remaining stations have positive slopes which indicate the air quality have gotten worse especially Kemaman as it has the highest slope in this region.

For Sarawak Region, the highest daily maximum mean of API is recorded in Permyjaya with 386.83 which is in the Hazardous status (API: 301-500). For overall mean of API, Bintulu has the highest mean with 37.90, whereas Limbang has the lowest mean with 26.01. The coefficient variation of monitoring stations in this region are spatially varied in between 34.91% to 83.26%. With the highest CV, Permyjaya has showed the greatest level of dispersion relative to the mean. For trend analyses, the positive significant trends can be observed in all monitoring stations, with the exception of Kota Samarahan station. This shows that in Sarawak, the air quality was not getting better but instead, was getting unhealthier with Miri experienced the worst air quality deterioration where it has the highest slope in Sarawak region. In Sabah Region, the highest daily maximum mean of API is recorded in Tawau with 152.53 which has fell into the Unhealthy status (API: 101-200). In spite of this, Kota Kinabalu is the one that has the highest overall mean of API with 33.13 while Keningau has the lowest mean with 29.12. In this region, daily API has showed considerable spatial variation with coefficient variation in range of 29.87% to 36.06%. With an exception of Keningau monitoring station, all of the stations in Sabah Region have significant trend where Kota Kinabalu showed an increasing trend while the others showed decreasing trends. Therefore, in this region, Kota Kinabalu is the only station that has air quality that becoming unhealthful throughout the year 2010 to 2016.

Frequency of exceedance (%) was used to further assess the Air Pollution Index (API) in Malaysia in order to assess the impacts exposed to the human by the air quality, which is calculated by the the percentage of exceeding the Good level of pollution (API: 0-50) in each monitoring stations were identified. Further details of the frequency exceedance (%) of API more than 50 for each monitoring stations in the six studied Regions are shown in Figure 1. By comparing the frequency of exceedance between all the studied monitoring Regions, Klang Valley was identified to have the highest mean for overall frequency of exceedance. This probably because it is in a mainstream economic region in Malaysia with the massive physical development of the infrastructure, industrialisation and urbanisation which have significantly deteriorated the air quality [10]. Klang Valley has been recognized as the well-most-developed area in Malaysia where the capital city of the country is also known to be a part of this region. All of the maximum percentages for every year in this region have exceeding 50% of the API good level of air pollution, which is more than half a year people in Klang Valley have exposed to the poor air, especially on 2015. Additionally, on 2015, around 64% of the population in this region was analytically exposed to the unhealthy air quality conditions. As the Southern Peninsular is the second most industrialized and urbanized region, this made the Region to have the second highest mean for overall frequency of exceedance. All of the frequencies can be seen to be more than 10%. Bukit Rambai has showed a distinct pattern of having a consistent high percentage of exceedance on the earlier years (2011 – 2013) which causing it to be recorded as the hotspot area in Malaysia for these three consecutive years. This monitoring station is located in industrial area in southern part of Malaysia. Thus, the pollutants released from the manufacturing facilities in furniture and wood industry could worsened the air quality and hence, could reduce the health of human through short-term or long-term effect [12].

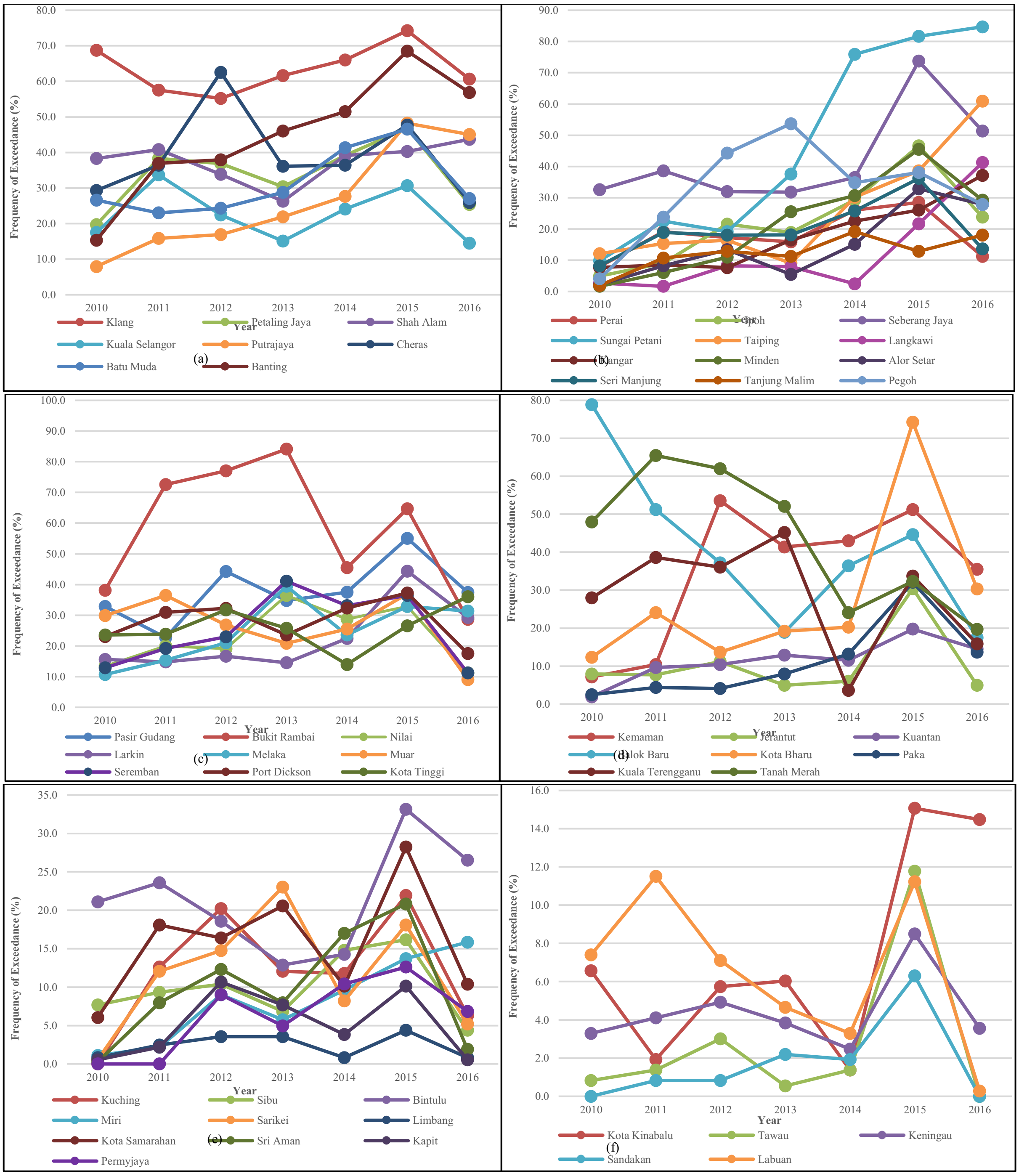

Figure 1. Frequency of exceedance (%) Good level of pollution (API: 0-50) in each monitoring stations for six studied Regions (a) Klang Valley; (b) Northern Region; (c) Southern Region; (d) East Coast; (e) Sarawak; and (f) Sabah.

Additionally, Melaka is observed to have the highest increase in exceedance for this region on 2010 to 2016. This may because of the high particulate events (HPE) on 2013 and 2014 along with the super El-Nino occurrence on 2015 to 2016. HPE caused a higher temperature and a clear fluctuation in concentrations of pollutants [13]. Hence, this increased the number of unhealthy days in an urban area of Melaka.

For Sarawak and Sabah Region, there can be seen having a relatively low frequency of exceedance that may due to its lower population density. In addition, it is also a less-industrialised region when compared to the other regions in Peninsular Malaysia .In Sarawak, all of the monitoring stations have undergone fluctuations in term of exceedance with the distinct increase occurred in 2015. Among all stations, Bintulu was seen to have a relatively high frequency of exceedance throughout the years. According to [14], this station is located near to the industrial area dominated by petrochemical industries. While in Sabah, the smaller fluctuations were observed compared to Sarawak. Plus, the clear rise of frequency of exceedance could be seen in 2015 which are similar to every other region. In this region, Kota Kinabalu has showed the highest increase in exceedance from 2010 to 2016. It has also showed a tremendous increase of exceedance in 2015 and thenceforth, continue to escalate which causing it to reach the highest frequency for this region on 2016. This may probably because it is the most urbanized city in Sabah. Considering it to be a more developed area compared to the other monitoring stations in this region, it has received a greater impact of haze episodes. Plus, the expansion of city areas and high number of motor vehicles are also the main factor of high exceedance in this station. According to [15] motor vehicle exhaust emissions and gases released from industrial activities are the main sources of air pollution in this station.

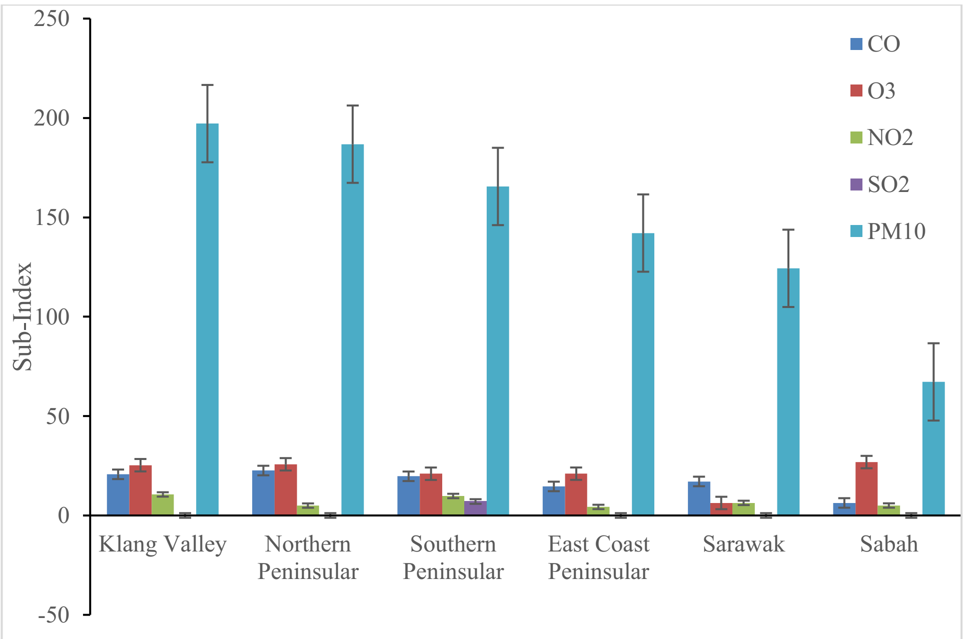

Figure 2. Sub-indexes of Air Pollution Index (API) for six monitoring regions which involves Klang Valley Region; Northern Peninsular Region; Southern Peninsular Region; East Coast Peninsular; Sarawak; and Sabah.

Based on the calculations of Air Pollution Index (API), main pollutant that mainly be a contributor to the API reading is particulate matter (PM_{10}). This is because its sub-index often has the highest value compared to the sub-index of other pollutants. Figure 2 shown the daily sub-indexes for each main pollutants which are carbon monoxide (CO), ground-level ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and particulate matter (PM_{10}) in the six monitoring Regions. Particulate matter (PM_{10}) is a suspended solid or liquid particle existing in air which include the aerosols, dust, soot, ashes, smoke, spores and more. One factor which may explain why PM_{10} has frequently contributed to the API reading is because it is mostly observed near the surface and its mechanism formation is different from gases [16]. Particulate matter could be originated from both natural and anthropogenic sources as either a primary or secondary pollutant. Particulate matter may have emitted into the atmosphere in the primary form from the volcanic eruptions, construction sites, vehicles, fires and more. The particulate matter could also have appeared in secondarily formed where have previously undergo further attachment to the environmentally persistent free radicals and biologically active chemicals such as metals (toxic) and organic compounds (PAHs) [17]. Thus, the variation of forms and sources of particulate may have contributed to its higher concentration and therefore, having higher sub-index. In addition, according to [18], particulate matter with a smaller size has a longer residence time which could remain in the atmospheric for several days or weeks and also subjected to movement through the atmospheric circulation. The particulate could also be transported to even more distant locations and even with no anthropogenic emission found in the area.

4. Conclusion
In conclusion, more than half of the monitoring stations in Malaysia have positive significant trends. This indicates that the Air Pollution Index (API) in Malaysia overall is increased and the air quality has gotten worse during the year 2010-2016. Next, for the frequency of exceedance which surpassed the API Good level (API > 50) was recorded the highest in Klang Valley and Southern Region that mainly due to high urbanized and industrialization, however for Sarawak and Sabah Regions shown the lowest exceedance. Meanwhile the contributing pollutant during that period was found to be from particulate matters (PM_{10}).

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