FINAL REPORT

REVIEW OF AIR POLLUTANT INDEX (API)

Prepared For:

Department of Environment
Ministry of Natural Resources & Environment

Project Title:

Review Of Air Pollutant Index (API)

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List of Abbreviation

AQI	Air Quality Index
ASMA	Alam Sekitar Sdn. Bhd
Aus-AQI	Australian Air Quality Index
Cas-AQHI	Canada Air Quality Health Index
CO	Carbon monoxide
DAQI	United Kingdom Daily Air Quality Index
DOE	Malaysian Department of Environment
EU-CAQI	European Union Common Air Quality Index
MY-API	Malaysian Air Pollutant Index
NO_2	Nitrogen dioxide
O_3	Ozone
PM_{10}	Particulate matter with aerodynamic diameter below than 10 micrometer
$PM_{2.5}$	Particulate matter with aerodynamic diameter below than 2.5 micrometer
ppb	Parts per billion
ppm	Parts per million
RMAQG	Recommended Malaysian Air Quality Guideline
SO_2	Sulfur dioxide
USEPA	United States Environmental Protection Agency
$\mu g/m^3$	Microgram per cubic meter
1-h	Hourly average concentration
8-h	8 hour average concentration
24-h	24 hour average concentration

Executive Summary

Air pollutants index is an indicator of the concentration of air pollutants to human health. There are many different methods to calculate the index to correlate air pollutants to human health around the world. Among these are the air quality index introduced by the United States Environmental Protection Agency (USEPA), Daily Air Quality Index (United Kingdom), Common Air Quality Index (European Union), Canada Air Quality Health Index (Canada) and Australian Air Quality Index. In this report we used daily air quality data in 2005 to calculate the air quality index using these different methods of calculation. The results show that the indices are correlated with each other. The best method to calculate air quality index for Malaysia is still USEPA method due to its comprehensive health impact consideration and its use by our neighboring countries. Particulate matter was found to be the major air pollutant for air pollutant index (API) in Malaysia. The breakpoints of all pollutants for Malaysian API calculation is suggested to follow the breakpoints based on health implication recommended by USEPA. The breakpoints for particulate matter below 2.5 micrometer ($PM_{2.5}$) may follow the suggested standard of $PM_{2.5}$ for Malaysia in 2015 (IT-1), 2018 (IT-2) and 2020 (IT-3). The Department of Environment (DOE) is suggested to revise the breakpoints of each pollutant from time to time based on new finding on air pollutants effect to human health and new development of international protocol.

Project Background

1.1 Introduction

Air pollution is a major concern in our society these days. Air pollutants can be generated from various natural and man-made sources. Emission from sea surface, forested areas and soil dust are some of the natural sources of air pollutants. These sources usually contribute to the background level of air pollutants in ambient air. Other than natural sources, various man-made activities such as emission from motor vehicles, industrial activities and biomass burning may also contribute to the high level of air pollutants in ambient air[1, 2]. Since the beginning of industrial era in 19th century, man-made sources air pollutants seem to dominate the level of air pollutants in ambient air[3], greatly deteriorating the air quality. As polluted air can cause various health complications to human, the ability to disseminate information on the severity of air pollution at a particular time and region to the public and policy makers is therefore important.

The necessity and development of air quality index began in 1950s after the fatal episode experienced by New York and London due to air pollution caused by sulfur dioxide and particulates in the form of smoke shade. The study by Manos and Fisher [4] is among the earliest studies to devise an index of air pollution to relate the variation of mortality in the metropolitan areas of United States of America (USA). Indices of sulfur dioxide and smoke shade were then proposed to relate air pollution to health effects, thus defining the level of concentration of sulfur dioxide and smoke shade to 'Desired level', 'Alert level' and 'Extreme level'[5]. Later, the states and local agencies in USA were more involved in the process to inform the daily air pollution level to the public using different types of air pollution index. Meanwhile, Ott and Thorn [6,] Thom and Ott [7] proposed a uniform index of air pollution in the states within USA and Canada. Thus, air quality index (AQI) was designed to be a simple numerical scale mechanism to correlate air pollutants concentration to human health. The AQI scale represents a broad range of air quality ranging from pristine air to "hazardous air" and focuses on the health effects a person may experiences within a few hours or days after being exposed to the polluted air.

There are many approaches to calculate AQI based on different considerations. Every index has its own characteristics strengths and weaknesses that can determine its suitability for particular applications to identify the vulnerable zone and show the level of severity of air pollution to public[8]. The most widely used AQI is that of introduced by United State Environmental Protection Agency (USEPA). USEPA calculates the AQI for five major air pollutants regulated by the US Clean Air Act: 1) ground-level ozone, 2) particle pollution (also known as particulate matter), 3) carbon monoxide, 4) sulfur dioxide, and 5) nitrogen dioxide. For each of these pollutants, various standards have been established to protect public health[9-11]. In principle, the final AQI for the air quality of a given area is calculated based on the aggregation of pollutant AQIs as well as individual pollutant AQI.

The final AQI is known as total AQI. Several studies applied the aggregation of pollutants concentration to estimate the total AQI[12-14]. However, the total AQI determined based on the aggregation of pollutants can provide false positive alarm even though the air is less polluted[15]. Hence, while the USEPA determines the AQI of the five pollutants as mentioned above, the reported total AQI for the air quality uses the AQI of the pollutant with the highest index value among these five pollutants considered. Many countries around the world including the Southeast Asian countries has been referring to USEPA AQI calculation formula, using it as a predominant approach to develop their own air pollutant index[16-20]. A careful and detail consideration of selecting which AQI method to be used is the first step to reduce the ambiguity when presenting the real picture of air pollution at a certain area or region to the public and policy makers.

1.2 Air Quality Index by United State Environmental Protection Agency (USEPA).

The Air Quality Index (AQI) introduced by USEPA[21] is the most popular air quality index. It is adopted by many countries in the world including Malaysia. The AQI runs from index value 0 to 500. The higher the AQI value is, the greater the level of air pollution, and hence greater is the health concern. An AQI value of 50 indicates that the air quality is good and is with little potential negative implication to the public health, while an AQI value over 300 represents hazardous air quality. An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, a level which USEPA has set

to protect public health. AQI values below 100 are generally thought of as satisfactory air quality. When the AQI value is above 100, the air quality is considered to be unhealthy for certain sensitive groups of people. Should the AQI value get any higher, the air quality is then considered to be unhealthy for everyone. The purpose of establishing AQI is to help ordinary people to understand on what scale the local air quality is impacting the human health, and how their daily life is hence being impacted. Overall USEPA AQI is divided into six categories (Table 1.1). Each category corresponds to a different level of health concern.

Table 1.1 Levels of AQI and their meaning to community health

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0 - 50	Air Quality is considered satisfactory, and air pollution poses little or no risk.
Moderate	51 - 100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are usually sensitive to air pollution.
Unhealthy for Sensitive Groups	101 - 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 - 200	Everyone may begin to experience health effects, members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 - 300	Health alert: everyone may experience more serious health effects.
Hazardous	> 300	Health warnings of emergency conditions. The entire population is more likely to be affected.

The calculation of AQI is using an equation (Eq. 1.1), pollutant concentration data and break points of air pollutants (Table 1.2). Table 1.3 shows the pollutant-specific sub-indices and cautionary statements for guidance on the Air Quality Index (AQI). Table 1.4 shows the summary of latest breakpoints of each pollutants use for the AQI calculation since December 2013[22] .

The generalized equation of AQI calculation

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (X_P - BP_{Lo}) + I_{Lo} \qquad \text{(Eq. 1.1)}$$

Where I_p = the index for pollutant p

X_p = the rounded concentration of pollutant p

BP_{Hi} = the breakpoint that is greater than or equal to X_p

BP_{Lo} = the breakpoint that is less than or equal to X_p

I_{Hi} = the AQI value corresponding to BP_{Hi}

I_{Lo} = the AQI value corresponding to BP_{Lo}

A specific color code will be assigned to each AQI category to make it easier for the public to understand quickly whether air pollution is reaching unhealthy levels in their community. For example, the color orange means that air quality conditions are “unhealthy for sensitive groups,” while red means that conditions may be “unhealthy for everyone”. The color code use by USEPA is shown in Figure 1.1:

Figure 1.1: Color code assigned by USEPA to each AQI category.

Table 1.2 Pollutant-Specific Sub-indices and Health Effects Statements for Guidance on the Air Quality Index (AQI)*

API Categories: Index Values	Ozone (ppm)		Particulate Matter(µg/m^3)		Carbon Monoxide (ppm) [8-h]	Sulfur Dioxide (ppb) [1-hour]	Nitrogen Dioxide (ppb) [1-hour]
	[8-h]	[1-h]	$PM_{2.5}$ [24-h]	PM_{10} [24-h]			
Good (Upto50)	0 - 0.059 None		0-12.0 None	0-50 None	0-4.4 None	0 - 35 None	0 - 53 None
Moderate (51-100)	0.060 - 0.075		12.1-35.4	50-150	4.5-9.4 None	36 - 75 None	54 - 100 None
	Unusually sensitive individuals may experience respiratory symptoms.		Respiratory symptoms possible in unusually sensitive individuals, possible aggravation of heart or lung disease in people with cardiopulmonary				
Unhealthy for Sensitive Groups (101-150)	0.076 - 0.095	0.125-0.164	35.5-55.4	150-250	9.5-12.4	76 - 185	101 - 360
	Increasing likelihood of respiratory symptoms and breathing discomfort in active children and adults and people with lung disease, such as asthma.		Increasing likelihood of respiratory symptoms insensitive individuals, aggravation of heart or lung disease and premature mortality in people with cardiopulmonary disease and older adults.		Increasing likelihood of reduced exercise tolerance due to increased cardiovascular symptoms, such as chest pain, in people with heart disease.	Increasing likelihood of respiratory symptoms, such as chest tightness and breathing discomfort, in people with asthma.	Increasing likelihood of respiratory symptoms, such as chest tightness and breathing discomfort, in people with asthma.
Unhealthy (151-200)	0.096 - 0.115	0.165-0.194	55.5-150.4	250-350	12.5-15.4	186 - 304	361-649
	Greater likelihood of respiratory symptoms and breathing difficulty inactive children and adults and people with lung disease, such as asthma; possible respiratory effects in general population.		Increased aggravation of heart or lung disease and premature mortality in people with cardiopulmonary disease and older adults; increased respiratory effects in general population.		Reduced exercise tolerance due to increased cardiovascular symptoms, such as chest pain, in people with heart disease.	Increased respiratory symptoms, such as chest tightness and wheezing in people with asthma; possible aggravation of heart or lung disease.	Increased respiratory symptoms, such as chest tightness and wheezing in people with asthma; possible aggravation of other lung diseases.

Continuation of Table 1.2

Very Unhealthy (201-300)	0.116 - 0.374	0.195-0.404	150.5-250.4	350-420	15.5-30.4 Significant aggravation of cardiovascular symptoms, such as chest pain, in people with heart disease.	305 – 604 [24-hour] Significant increase in respiratory symptoms, such as wheezing and shortness of breath, in people with asthma; aggravation of other lung diseases.	650 - 1249 Significant increase in respiratory symptoms, such as wheezing and shortness of breath, in people with asthma; aggravation of other lung diseases.
	Increasingly severe symptoms and impaired breathing likely inactive children and adults and people with lung disease, such as asthma; increasing likelihood of respiratory effects in general population.		Significant aggravation of heart or lung disease and premature mortality in people with cardiopulmonary disease and older adults; significant increase in respiratory effects in general population.				
Hazardous(301-500)	--	0.405-0.60	250.4-500.4	420-600	30.5-50.4 Serious aggravation of cardiovascular symptoms, such as chest pain, in people with heart disease; impairment of strenuous activities in general population.	605 – 1004 [24-hour] Severe respiratory symptoms, such as wheezing and shortness of breath, in people with asthma; increased aggravation of other lung diseases; possible respiratory effects in general population.	1249 - 2049 Severe respiratory symptoms, such as wheezing and shortness of breath, in people with asthma; increased aggravation of other lung diseases; possible respiratory effects in general population.
	Severe respiratory effects and impaired breathing likely inactive children and adults and people with lung disease, such as asthma; increasingly severe respiratory effects likely in general population.		Serious aggravate on of heart or lung disease and premature mortality in people with cardiopulmonary disease and older adults; serious risk of respiratory effects in general population.				

Source: USEPA[22]

Table 1.3 Pollutant-Specific Sub-indices and Cautionary Statements for Guidance on the Air Quality Index (AQI)

API Categories (Index Values)	Ozone (ppm)		Particulate Matter(µg/m^3)		Carbon Monoxide (ppm) [8-h]	Sulfur Dioxide (ppb) [1-hour]	Nitrogen Dioxide (ppb) [1-hour]
	[8-h]	[1-h]	$PM_{2.5}$ [24-h]	PM_{10} [24-h]			
Good (Up to 50)	None		0-12 None	0-50 Non	0-4.4 None	0 - 35 None	0 - 53 None
Moderate (51-100)	0.060 - 0.075		12.1-35.4	50-150	4.5-9.4 None	36 - 75	54 - 100 Unusually sensitive individuals should consider limiting prolonged exertion especially near busy roads.
	Unusually sensitive people should consider reducing prolonged or heavy outdoor exertion.		Unusually sensitive people should consider reducing prolonged or heavy exertion.				
Unhealthy for Sensitive Groups (101-150)	0.076 - 0.095	0.125-0.164	-	-	9.5-12.4 People with heart disease, such as angina, should limit heavy exertion and avoid sources of CO, such as heavy traffic.	76 - 185 People with asthma should consider limiting outdoor exertion.	101 - 360 People with asthma, children and older adults should limit prolonged exertion especially near busy roads.
	People with lung disease, such as asthma, children, older adults, and outdoor workers should reduce prolonged or heavy outdoor exertion.		People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.				

continuation of Table 1.3

Unhealthy (151-200)	0.096 - 0.115	0.165-0.194	55.5-150.4	250-350	12.5-15.4 People with heart disease, such as angina, should limit moderate exertion and avoid sources of CO, such as heavy traffic.	186 – 304 Children, people with asthma, or other lung diseases, should limit outdoor exertion	361 – 649 People with asthma, children and older adults should avoid prolonged exertion near roadways; everyone else should limit prolonged exertion especially near busy roads.
	People with lung disease, such as asthma, children, older adults, and outdoor workers should avoid prolonged or heavy outdoor exertion; everyone else should reduce prolonged or heavy outdoor exertion.		People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion.				
Very Unhealthy (201-300)	0.116 - 0.374	0.195-0.404	150-250	350-420	15.5-30.4 People with heart disease, such as angina, should avoid exertion and sources of CO, such as heavy traffic.	305 – 604 [24-hour] Children, people with asthma, or other lung diseases should avoid outdoor exertion; everyone else should reduce outdoor exertion.	650 - 1249 People with asthma, children and older adults should avoid all outdoor exertion; everyone else should avoid prolonged exertion especially near busy roads.
	People with lung disease, such as asthma, children, older adults, and outdoor workers should avoid all outdoor exertion; everyone else should reduce outdoor exertion.		People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.				
Hazardous (301-500)	-	0.405-0.604	250-500	420-600	30.5-50.4 People with heart disease, such as angina, should avoid exertion and sources of CO, such as heavy traffic; everyone else should limit heavy exertion	604 – 1004 [24-hour] Children, people with asthma, or other lung diseases, should remain indoors; everyone else should avoid outdoor exertion.	1250 - 2049 People with asthma, children and older adults should remain indoors; everyone else should avoid all outdoor exertion.
	Everyone should avoid all outdoor exertion.		Everyone should avoid all physical activity outdoors; people with heart or lung disease, older adults, and children should remain indoors and keep activity level slow.				

Source: USEPA [22]

Table 1.4 Breakpoints values for the AQI calculation based on USEPA

Category	AQI	Parameter Breakpoint						
Parameter		O_3 (ppm)	O_3 (ppm)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)
Averaging Time		8-h	1-h	24-h	24-h	8-h	1-h	1-h
Good	0-50	0.000-0.059	-	0-54	0.0-12.0	0.0-4.4	0.000-0.035	0.000-0.053
Moderate	51-100	0.060-0.075	-	55-154	12.1-35.4	4.5-9.4	0.036-0.075	0.054-0.100
Unhealthy for Sensitive Groups	101-150	0.076-0.095	0.125-0.164	155-254	35.5-55.4	9.5-12.4	0.076-0.185	0.101-0.360
Unhealthy	151-200	0.096-0.115	0.165-0.204	255-354	(55.5-150.4)[3]	12.5-15.4	(0.186-0.304)[4]	0.361-0.649
Very unhealthy	201-300	0.116-0.374	0.205-0.404	355-424	(150.5-250.4)[3]	15.5-30.4	(0.305-0.604)[4]	0.650-1.249
Hazardous	301-400	([2])	0.405-0.504	425-504	(250.5-350.4)[3]	30.5-40.4	(0.605-0.804)[4]	1.250-1.649
Hazardous	401-500	([2])	0.505-0.604	505-604	(350.5-500.4)[3]	40.5-50.4	(0.805-1.004)[4]	1.650-2.049

[1]Areas are required to report the API based on 8-h ozone values. However, there are areas where an API based on 1-h ozone values would be more protective. In these cases the index for both the 8-h and the 1-h ozone values may be calculated and the maximum API reported.
[2]8-h O_3 values do not define higher AQI values (≥ 301). AQI values of 301 or higher are calculated with 1- h O_3 concentrations.
[3]If a different SHL for $PM_{2.5}$ is promulgated, these numbers will change accordingly.
[4]1-h SO_2 values do not define higher AQI values (≥ 200). AQI values of 200 or greater are calculated with 24-h SO_2 concentrations.

Source: USEPA[22]

1.3 Malaysian Air Pollutant Index (MY-API)

Air quality index for Malaysia is reported as Air Pollutant Index (API). The calculation of API is based on USEPA calculation using five major air pollutants namely particulate matter as PM_{10}, ozone (O_3), carbon monoxide, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). Calculation of sub-index of each pollutant ($\mu g/m^3$ for PM_{10} and ppm for gases) is based on each sub-index formula (Appendix 1). The highest sub-index will become the API value for that particular time. API report is published in Malaysian Department of Environment's website with API category as shown in Table 1.5

Malaysian API sub-index value of 100 of a certain pollutant corresponds to the concentration of that pollutant considered being at the "safe level" by Recommended Malaysian Air Quality Guideline (RMAQG). If the API value exceeds 100, the air quality at that particular time and place is likely to cause health complication to general public. In Malaysia API, the API sub-index value of 0 to 100 is calculated directly from the linear increase of the concentration of a certain air pollutant. Therefore, the pollutant concentration breakpoint used to decide API sub-index value 50 is corresponding to the 50^{th} percentile of the RMG concentration standard for that air pollutant. Air pollutant concentration breakpoints used to determine the API sub-index of a certain pollutant at level 200, 300, 400 and 500 are however directly mirrored those of the AQI system in the USA[23].

Table 1.5: Scale for API based on health classification

API	Air Pollution Level
0 – 50	Good
51 – 100	Moderate
101 – 200	Unhealthy
201 - 300	Very unhealthy
301 - 500	Hazardous

1.4 United Kingdom Daily Air Quality Index (DAQI)

The Daily Air Quality Index (DAQI) in United Kingdom depends on the pollutant concentrations averaged over specified periods (Table 1.6). These averaging periods were specifically selected by the 'Committee on the Medical Effects of Air Pollutants' (COMEAP) on the basis of epidemiological studies concerning the short-term impacts of air pollution (Table 1.7). With these specifications, the air quality index is inherently a 'daily' index. It is not possible to display values representing shorter time periods (for example 3 hourly) without distorting the intended meaning of the index. The daily air quality index comes in three parts, and includes additional advice for susceptible individuals, alongside with the advice for the general population.

The daily air quality index (DAQI) has been developed to provide advice on expected levels of air pollution. In addition, information on the short-term effects on health that might be expected to occur at the different bands of the index ("Low", "Moderate", "High", "Very High") is provided. It is possible that very sensitive individuals may experience health effects even on "Low" air pollution days. This advice applies to anyone experiencing symptoms[24].

1.5 European Union Common Air Quality Index (EU-CAQI)

The Common Air Quality Index (CAQI), covering the most relevant air pollutants, was defined by the Citeair project (http://www.citeair.eu and http://www.airqualitynow.eu). To present the air quality situation in European cities in a comparable and understandable way, all detailed measurements are transformed into a single relative figure. The CAQI converts the concentrations of pollutants into one air quality index. The higher the CAQI is, the worse is the experienced air quality. The CAQI considers relevant atmospheric pollutants that cause unfavorable conditions, which are ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO)[25], sulfur dioxide (SO_2), particulate matter (PM_{10}), fine particles ($PM_{2.5}$). The CAQI is determined by the pollutant with the highest concentration. Elevated CAQI values are due to enhanced concentrations of at least one pollutant[26]. The CAQI is calculated first by applying observed or forecasted values for the six pollutants considered at a certain location.

Table 1.6: The bandings for the Daily Air Quality Index based on major air pollutants

Bandings for the Daily Air Quality Index						
Band	**Index**	**Ozone**	**Nitrogen Dioxide**	**Sulphur Dioxide**	**$PM_{2.5}$ Particles**	**PM_{10}Particles**
		Running 8 hourly mean	**Hourly mean**	**15 minute mean**	**24 hour mean**	**24 hour mean**
		µg/m^3	**µg/m^3**	**µg/m^3**	**µg/m^3**	**µg/m^3**
Low		0-33	0-67	0-88	0-11	0-16
		34-66	68-134	89-177	12-23	17-33
		67-100	135-200	178-266	24-35	34-50
Moderate		101-120	201-267	267-354	36-41	51-58
		121-140	268-334	355-443	42-47	59-66
		141-160	335-400	444-532	48-53	67-75
High		161-187	401-467	533-710	54-58	76-83
		188-213	468-534	711-887	59-64	84-91
		214-240	535-600	888-1064	65-70	92-100
Very High		241 or more	601 or more	1065 or more	71 or more	101 or more

Sources: http://www.metoffice.gov.uk/guide/weather/air-quality

Table 1.7: Health advice to accompany the Daily Air Quality Index

Air pollution banding	Value	Accompanying health messages for at-risk groups and the general population	
		At-risk individuals*	**General population**
Low 	**1-3**	**Enjoy** your usual outdoor activities.	**Enjoy** your usual outdoor activities.
Moderate 	**4-6**	Adults and children with lung problems, and adults with heart problems, **who experience symptoms**, should **consider reducing** strenuous physical activity, particularly outdoors.	**Enjoy** your usual outdoor activities.
High 	**7-9**	Adults and children with lung problems, and adults with heart problems, should **reduce** strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also **reduce** physical exertion.	Anyone experiencing discomfort such as sore eyes, cough or sore throat should **consider reducing** activity, particularly outdoors.
Very High 	**10**	Adults and children with lung problems, adults with heart problems, and older people, should **avoid** strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.	**Reduce** physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

Sources: http://www.metoffice.gov.uk/guide/weather/air-quality

The concentration of each constituent will then determine the index class as shown in Table 1.8. The aggregated CAQI value is finally determined by the highest (most enhanced) of the single pollutant CAQI values[26]. The distinct feature of the EU index is that it has set two indices i.e. one for roadside monitoring sites while another for average city background conditions. The EU directed member states are required to inform the public on the ambient air quality status based on CAQI[27].

Table 1.8: Common Air Quality Index (CAQI) calculation grid

Index Class	Grid	Traffic						City Background							
		Core Pollutant			Pollutant			Core Pollutant				Pollutant			
		NO_2	PM_{10}		$PM_{2.5}$		CO	NO_2	PM_{10}		O_3	$PM_{2.5}$		CO	SO_2
			1-h	24-h	1-h	24-h			1-h	24-h		1-h	24-h		
Very low	0 25	0 50	0 25	0 15	0 15	0 10	0 5000	0 50	0 25	0 15	0 60	0 15	0 10	0 5000	0 50
Low	25 50	50 100	25 50	15 30	15 30	10 20	5000 7500	50 100	25 50	15 30	60 120	15 30	10 20	5000 7500	50 100
Medium	50 75	100 200	50 90	30 50	30 55	20 30	7500 10000	100 200	50 90	30 50	120 180	30 55	20 30	7500 10000	100 350
High	75 100	200 400	90 180	50 100	55 110	30 60	10000 20000	200 400	90 180	50 100	180 240	55 110	30 60	10000 20000	350 500
Very High*	>100	>400	>180	>100	>110	>60	>20000	>400	>180	>100	>240	>110	>60	>20000	>500

NO_2, O_3, SO_2: 1-h value / maximum 1-h value in µg/m^3
CO: 8-h moving average / maximum 8-h moving average in µg/m^3
PM_{10} 1-h value / daily value in µg/m^3

*An index value above 100 is not calculated but reported as ">100"

Sources: Elshout, Bartelds [26]

1.6 Air Quality Index in Australia (Aus-AQI)

The calculation of Air Quality Index in Australia is based on the percentage of each pollutants compare to its standard. Each category in the AQI corresponds to a different level of health risk[28].

Very Good and Good:

AQI between 0 and 66.

Air quality is considered good, and air pollution poses little or no risk.

- **Fair:**

  AQI between 67 and 99.

  Air quality is acceptable. However, there may be a health concern for very sensitive people.

- **Poor:**

  AQI between 100 and 149.

  The air quality is unhealthy for sensitive groups, such as people with lung disease or heart disease. The general population is not likely to be affected.

- **Very Poor:**

  AQI values between 150 and 200.

  Everyone may begin to experience health effects, especially those from sensitive groups.

- **Hazardous:**

  AQI greater than 200.

  Everyone may experience health effects.

Calculation of the AQI for various pollutants from readings recorded at air monitoring stations using the following calculation (Eq. 1.2):

$$AQI_{pollutant} = \frac{pollutant\ data\ reading}{standard} \times 100 \qquad \text{(Eq. 1.2)}$$

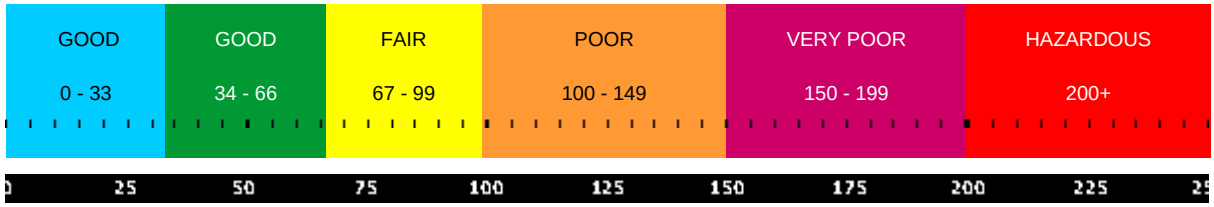
The highest level of pollutant recorded is the AQI for that site for that time period. A reading over 100 means that the pollutant level is higher than the standard. The Western Australia standards are based on health studies and standards from around the world, including the National Environment Protection Measure standards. Units of measurement of each pollutants and health indicator of are summarized in Table 1.9 and Table 1.10.

Table 1.9: Unit of air pollutants used for air quality index calculation

Pollutant	**Units used for air quality data**	
Carbon monoxide	ppm	(parts per million)
Nitrogen dioxide	ppb	(parts per billion)
Ozone	ppb	(parts per billion)
Particles	µg/m^3	(micrograms per cubic meter)
Sulfur dioxide	ppb	(parts per billion)
Visibility (as B_{sp})	10^{-4} m^{-1}	

Source: http://www.environment.nsw.gov.au/aqms/dataindex.htm[28]

Table 1.10: Category for Australian Air Quality Index



1.7 Canada Air Quality Health Index (Cas-AQHI)

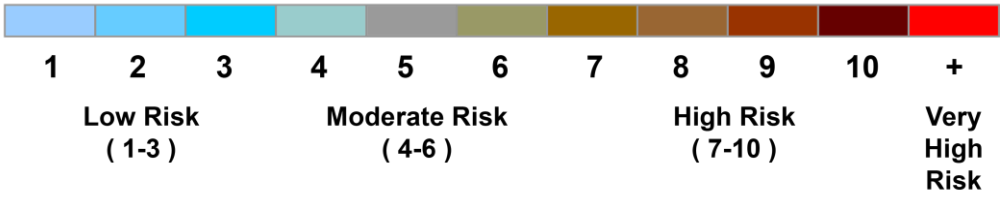
Canadian Air Quality Health Index (AQHI) is calculated based on the relative risks of a combination of common air pollutants that is known to harm human health which are ozone (O_3), particulate matter (PM_{10}/$PM_{2.5}$) and nitrogen dioxide (NO_2). All three of these pollutants can pose significant health risks, even at low levels of exposure, especially among those with pre-existing health problems[25]. The formulation of the national AQHI is based on the observed relationship of these pollutants with mortality from an analysis of several Canadian cities.

The national AQHI is calculated based on three-hour average concentrations of ground-level O_3, NO_2, and $PM_{2.5}$. O_3 and NO_2 are measured in parts per billion (ppb) while $PM_{2.5}$ is measured in micrograms per cubic metre (µg/m^3). The AQHI is calculated on a community basis (each community may have one or more monitoring stations). First, the AQHI will be calculated by taking into account the averaged concentration of the 3 substances (O_3, NO_2, $PM_{2.5}$) at each station within a community for the 3 preceding hours using formula:

$$AQHI = \left(\frac{1000}{10.4}\right) \times [(e^{0.000537 \times O_3} - 1) + (e^{0.000871 \times NO_2} - 1) + (e^{0.000487 \times PM_{2.5}} - 1)]$$

The result is then rounded to the nearest positive integer; a calculation less than 0.5 will be rounded up to 1.

The final AQHI will later be measured on a scale ranging from 1-10+, which then are grouped into health risk categories as shown below. These categories help one to easily and quickly identify his or her level of risk.



- 1-3 Low health risk
- 4-6 Moderate health risk
- 7-10 High health risk
- 10 + Very high health risk

The AQHI will be published with the health message to the general population as shown in Table 1.11.

Table 1.11: Air Quality Health Index and health messages to general population

Health Risk	Air Quality Health Index	Health Messages	
		At Risk Population*	General Population
Low	1 - 3	Enjoy your usual outdoor activities.	Ideal air quality for outdoor activities.
Moderate	4 - 6	Consider reducing or rescheduling strenuous activities outdoors if you are experiencing symptoms.	No need to modify your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High	7 - 10	Reduce or reschedule strenuous activities outdoors. Children and the elderly should also take it easy.	Consider reducing or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very High	Above 10	Avoid strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion.	Reduce or reschedule strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

*People with heart or breathing problems are at greater risk. Follow your doctor's usual advice about exercising and managing your condition

2.0 Objectives

The specific objectives of this project are:

a) Revise current Malaysian Air Pollutant Index (API) in accordance with the Malaysian Ambient Air Quality Guideline 2013.
b) Develop new method for calculating API.
c) Compare current API with newly developed API.
d) Propose new category for air quality status based on the newly developed API.

2.1 Scopes

The scopes of the project are:

a) To prepare an outline of the study and determine the scientific as well as quantitative methodologies that is involved in the implementation of the project.

b) To prepare a literature review on the development of new API as well compare the current API with those used regionally and globally.

c) Develop new method for calculating API in accordance with Malaysian Ambient Air Quality Guideline 2013.

d) Examine the need for adding a new category i.e. ‘unhealthy for sensitive group’

e) Study the impact of the new API on documents published by DOE such National Haze Action Plan.

f) Prepare a stand-alone program for API calculation using Microsoft Excel spreadsheet

g) Provide a booklet that is part of the research report as an attachment. The booklet will contain the following (but not limited to):

i. Acknowledgement

ii. Introduction

iii. API calculation method

iv. Health impact based on API scale and recommended preventive measures

2.3 Conceptual framework

The strategy for this study is will follow the conceptual of Air Pollutant Index (API) development as show on Figure 2.1. The study will consider the different air quality indices used in different countries and regions. Data from several air quality monitoring stations managed by Alam Sekitar Sdn. Bhd (ASMA) will be used for the new API calculations. The calculation of APIs also will emphasise on the data during haze episode in Malaysia especially in 2005. Health implication and new Malaysian Air Quality Standard will be the main factors for the selection of API calculation for Malaysia.

2.4 Methodology

a) *Literature review and outlining the studies scope*:

A comprehensive literature review will be conducted in order to identify the current implementation of Air Pollutant Index (API) in different countries and regions. Knowledge on factors that have been taken for API calculations as well as comparison between different API formulations will be taken into account in this study.

b) *Calculation of Air Quality Indices based on Malaysian Data*

The calculation of APIs based on different formula will be conducted using Malaysian air quality data. For this purpose, data from selected stations from different background will be used for API calculations. Data from haze and non-haze episode also will be used for comparison study. The calculation also will incorporate the new air quality guideline suggested by Malaysian Department of Environment.

c) *Development on New Air Pollutant Index*:

Based on the calculation of indices using different formulas, one new Air Pollutant Index for Malaysia will be selected. The selection will be based on the suitability of the calculation data to the new air quality guideline and health impact of major air pollutants based on literature information. The data of health impact during haze episode will be considered for the selection. New category of air pollutant such as $PM_{2.5}$ will be included into the calculation.

d) *Development of Reporting Procedures*

The spreadsheet for API calculation based on Excel will be developed to calculate the API for Malaysia within specific averaging time. This spreadsheet will be used for the API reporting. The API calculation will also be presented in the booklet on API.

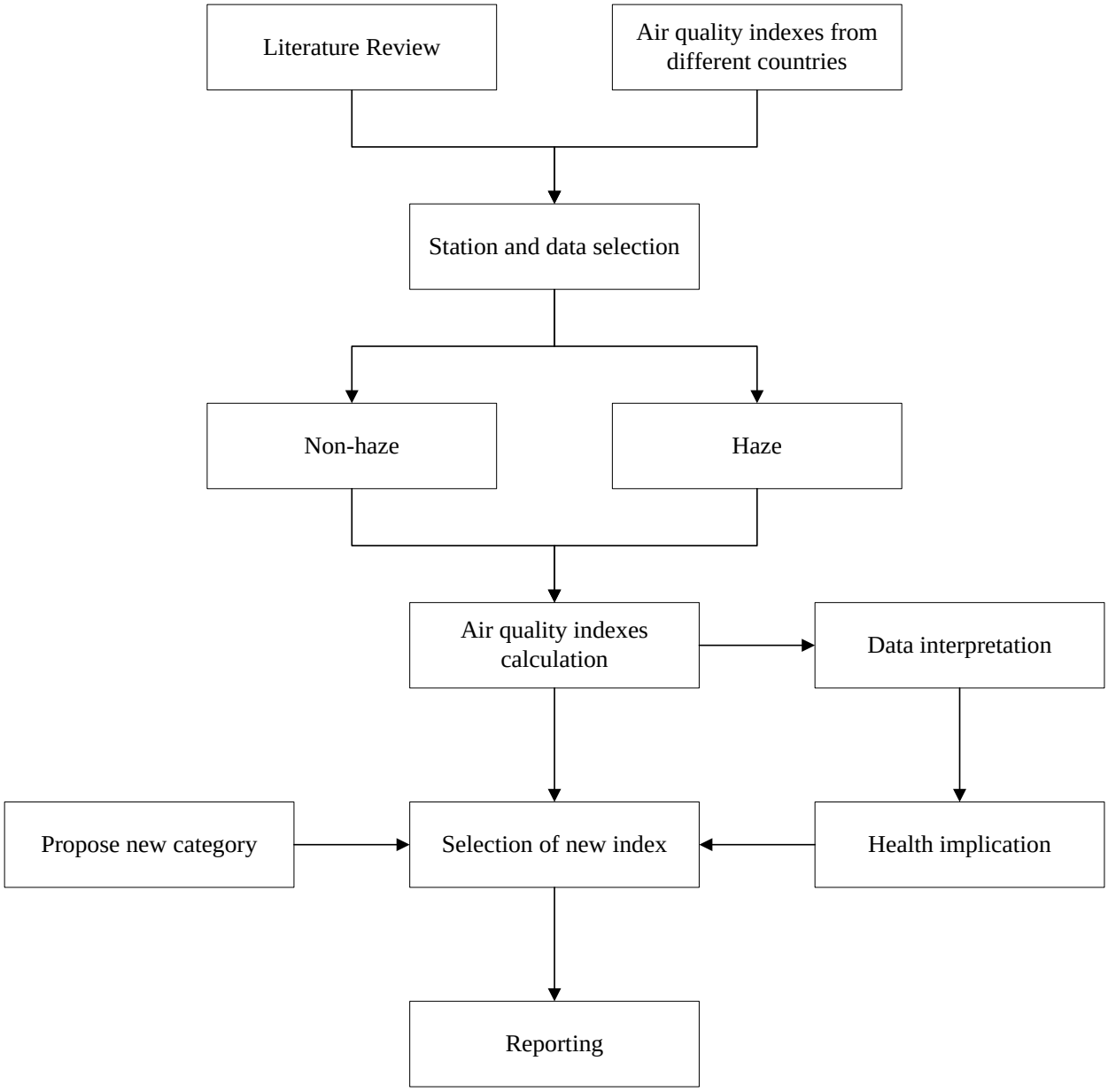


Figure 2.1 Conceptual framework for new Air Pollutant Index (API) development

3.0 Comparison of Malaysian MY-API Calculation with other Air Quality Indices (AQIs) Calculations

In this section we compare the air quality index calculated based on the different type of AQIs discussed above, namely the Malaysian Department of Environment API (MY-API), United State Environmental Protection Agency AQI (USEAP-AQI), United Kingdom Daily Air Quality Health Index (DAQI), Common Air Quality Index for European Countries (EU-CAQI), Australia Air Quality Index (Aus-AQI) and Canada Air Quality Health Index (Cas-AQHI). The results of the calculation for eight stations using PM_{10} data in 2005 (year with haze episode) based on different index are shown in Figure 3.1. Figure 3.2 highlights the background station, Jerantut and urban station Petaling Jaya. Based on the calculation, all indices (based on guideline in Appendix A- D) show that the air pollution indices during normal days were "moderate" while the concentration during haze episode was "hazardous" or very high.

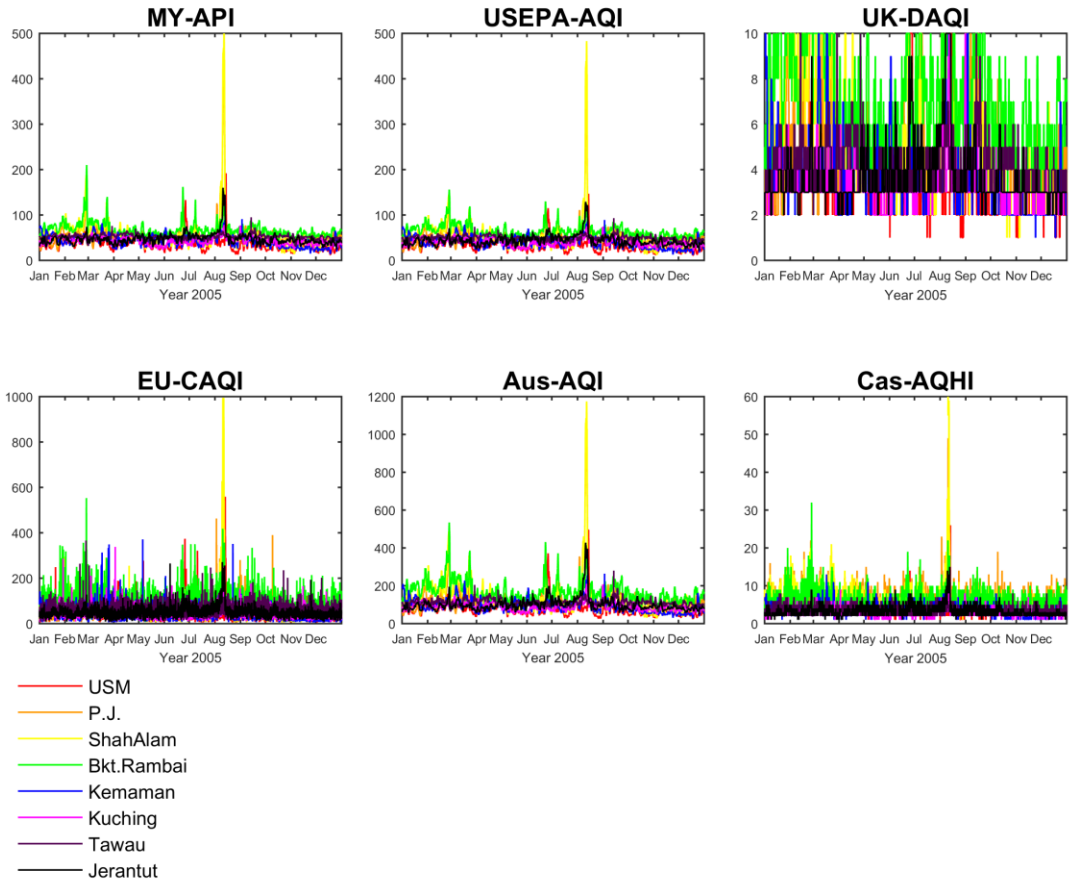


Figure 3.1 API index values for PM_{10} calculated based on MY-API, USEPA-AQI, UK-DAQI,

EU-CAQI, AUS-AQI and Cas-AQHI for eight selected stations.

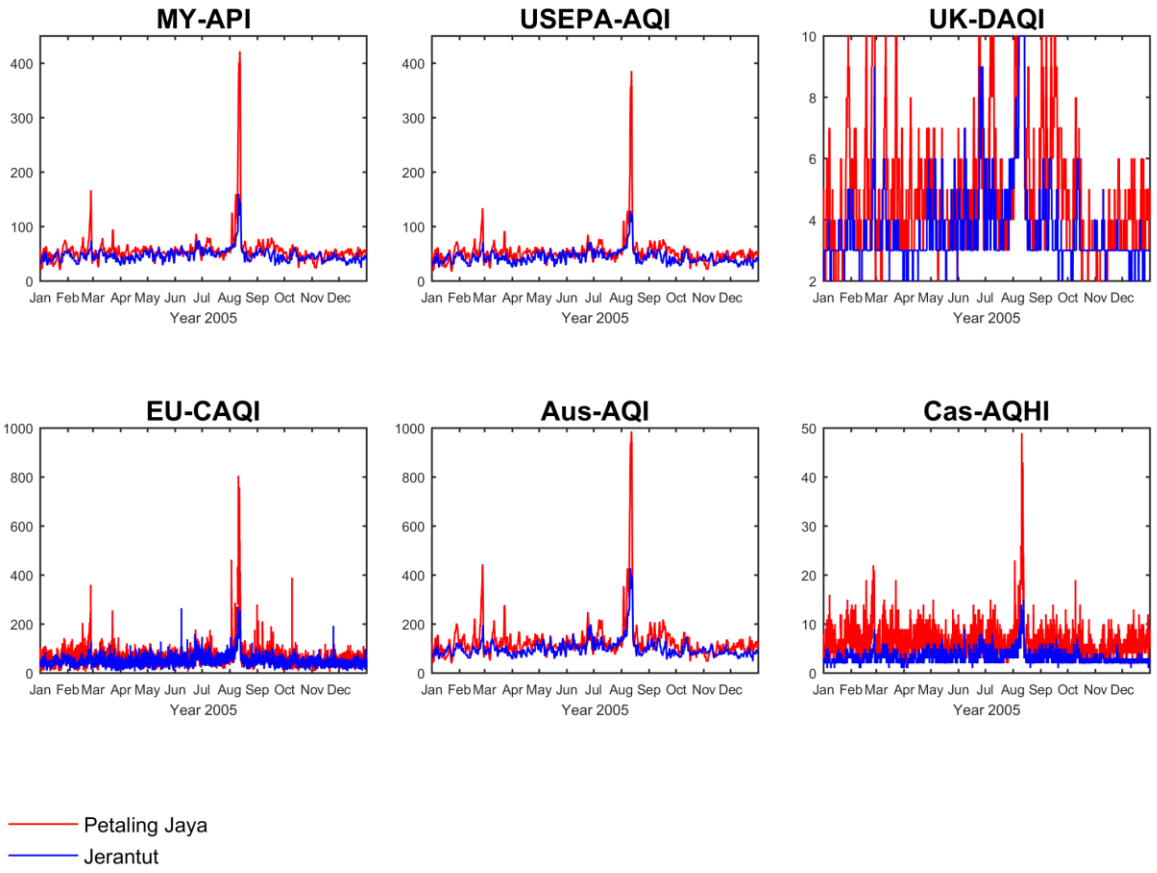


Figure 3.2 API index values for PM_{10} calculated based on MY-API, USEPA-AQI, UK-DAQI, EU- CAQI, AUS-AQI and Cas-AQHI for Jerantut (background station) and Petaling Jaya (urban station).

Comparison among all parameters during haze episode in 2005 (Table 3.1) shows that PM_{10} is the determinant of the air pollutants index during haze episode. Other parameters show index values between "good" and "moderate". The level of PM_{10} during haze episode can be classified as "hazardous" and "very high" which requires everyone to avoid all physical activity outdoors; people with heart or lung disease, older adults, and children should remain indoors and keep activity levels low.

Table 3.1 Index value and health advisory based on Malaysian (MY-API), United States (USEPA-AQI), United Kingdom (UK-DAQI), Europe (EU-CAQI), Australia (AUS-AQI) and Canada (Cas-AQHI) Indices for Petaling Jaya during a haze period (2005-08-11, 0900).

Param. / Calc.	O_3	PM_{10}	NO_2	SO_2	CO
MY-API	**3, Good**	**401, Hazardous**	**74, Moderate**	**22, Good**	**64, Moderate**
	Low pollution and has no ill effect on health	Severe aggravation of symptoms and endanger health	Moderate pollution and has no ill effect on health	Low pollution and has no ill effect on health	Moderate pollution and has no ill effect on health
USEPA-AQI	**1, Good**	**358, Hazardous**	**29, Good**	**12, Good**	**63, Moderate**
	None	Everyone should avoid all physical activity outdoors; people with heart or lung disease, older adults, and children should remain indoors and keep activity levels low	None	None	None
UK-DAQI	**5, Index=1 (Low)**	**472, Index=10 (Very High)**	**58, Index=1 (Low)**	**10, Index=1 (Low)**	**N/A, Index=N/A**
	Adults and children with lung problems, and adults with heart problems, who experience symptoms, should consider reducing strenuous physical activity, particularly outdoors.	Adults and children with lung problems, adults with heart problems, and older people, should avoid strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often	Adults and children with lung problems, and adults with heart problems, who experience symptoms, should consider reducing strenuous physical activity, particularly outdoors.	Adults and children with lung problems, and adults with heart problems, who experience symptoms, should consider reducing strenuous physical activity, particularly outdoors.	N/A
EU-CAQI	**6**	**471.67 (>100)**	**50.76**	**10.48**	**6587**
	Very low	Very High	Medium	Very low	Low
Aus-AQI	**3**	**943.33**	**25.833**	**2**	**63.921**
	Air quality is considered good, and air pollution poses little or no risk.	Everyone may experience health effects.	Air quality is considered good, and air pollution poses little or no risk.	Air quality is considered good, and air pollution poses little or no risk.	Air quality is acceptable. However, there may be a health concern for very sensitive people.
Cas-AQHI	**22, Very High**			**N/A**	
	Very high health risk			N/A	

4.0 Advantages and Disadvantages of Air Quality Index Used and Its Suitability with Malaysian API

The main limitation in calculating the API base on our current API formula is that the health impact of each pollutant at different concentrations to human remains uncertain. Even though the current API is a modification of USEPA-AQI, the justification for the pollutant concentration breakpoints modified were not were not comprehensively documented. Hence, API calculated from this formula is less able to be used to convince the public about the actual air quality.

The air quality indices used in countries like Canada and UK, on the other hand, needs detail studies on the impact of major air pollutants to human health, which unfortunately is currently lacking in Malaysia. Therefore, even though the Cas-AQHI and UK-DAQI have divided the air quality in a more detail manner compare to other calculations, both the AQI calculations are currently unable to be implemented in Malaysia. Moreover, Cas-AQHI only emphasises on three major pollutants which are $PM_{2.5}$, O_3 and NO_2, while UK-DAQI does not consider CO. This approach although rationally acceptable in the sense that most API calculated in all formula will be dominated by the concentration of $PM_{2.5}$, and while $PM_{2.5}$, O_3 and NO_2 pollutants can pose health risk even at a low levels of exposure, we remain steadfast to the opinion that monitoring other pollutants such as SO_2 and CO remain relevant as the amount of traffic in Malaysia remains high.

The Eu-CAQI has two different categories for CAQI presentation, which are of the traffic and city backgrounds. They also categorise the pollutants into common pollutants and core pollutants in the city and city background stations. Pollutant such as O_3 however is not measured for the traffic background stations. Eu-CAQI consideration of different backgrounds considers the tolerance of people from different background to the level of air pollution, but since Malaysia does not separate the monitoring stations to different backgrounds; therefore Eu-CAQI is unsuitable for the use in Malaysia.

The Aus-AQI is the simplest way to calculate the API. Nevertheless, this type of calculation is only used by Australia. Adapting this API formula simplifies the API calculations, but since it is not adopted by other countries, this will cause complications when we are to compare our API with countries in the region.

The USEPA-AQI formula is the most popular AQI, and is used in many countries such as Singapore, China, Thailand, Korea, and India. More importantly, the determination of API by USEPA-AQI is based on comprehensive health consideration. This AQI is also tweak able, as several countries have tweaked the pollutants breakpoints used between different categories to suit the local conditions. This can be done if the countries have conducted their own health related studies with respect to local air pollution and population. In the same time, USEPA-AQI also provides a good and clear guideline in API reporting to the public, i.e. colour codes to indicate level of pollution. This provides Malaysia with a good reference in local API reporting. The downside of USEPA-AQI compared to other AQIs formula is that it does not separate the air quality into more detailed health categories like that of UK-DAQI and Cas-AQHI.

The advantages and disadvantages for Malaysia to calculate API based of different AQI calculations are summarized in Table 4.1. After weighing the pros and cons of all the AQI formula compared, and considering that health related studies to air pollution are currently very limited in Malaysia, we suggest that the Malaysian Environmental Department adopt the original USEPA-AQI formula with a minor tweaking to the breakpoint use for $PM_{2.5}$ (will be further discuss in section 4.0) in determining the API in Malaysia. The main rationales in choosing the USEPA-AQI formula are: i)scientific health based breakpoints, ii) robust interpretation with detailed information on health impact of each pollutants at different level with lower uncertainty, iii) tweak able if the country has proper health related studies to air pollutions, iv) provide good reference in communicating air quality to general public. Should Malaysia adopt the USEPA-AQI formula in determining its API, the pollutants concentration breakpoints values used can be modified when Malaysia has its own information on the health effects of major air pollutants at different concentrations.

Table 4.1: The advantages and disadvantages for Malaysia to adopt different formula for API calculation

Index	Advantages	Disadvantage
MY-API	• Used for the time being in Malaysia	• No specific information on health impact • Need revision. It was prepared in 1997 • Based on Recommended Malaysian Air Quality Guideline (RMAQG) for unhealthy and moderate level • No API from $PM_{2.5}$
USEPA-AQI	• Used by many countries in the world • Detailed information on health based on different pollutant concentration in different categories	• Only five categories from 0-500 • Based on different US meteorological and environmental condition
UK-DAQI	• 10 categories • Detailed health impact based on different categories	• Based on UK meteorological and environmental condition • Not considering CO
Eu-CAQI	• Information on traffic and city background • Used by most EU countries	• Need to separate stations into different categories – traffic and city background • Base on EU meteorological and environmental condition
Cas-AQHI	• Combination of three major air pollutants • 10 categories • Detailed health impact base on different categories	• Not include CO and SO_2 which can be considered as major pollutants in Malaysia
Aus-AQI	• Easy to calculate – based on percentage	• Not used by other countries

5.0 API Calculation Using Malaysian Air quality Data and Suggested Breakpoints

Based on the argument in Section 4.0 (Table 4.1), the new calculation of API for Malaysia is recommended to follow the formula suggested by USEPA with modification of breakpoints based on new Malaysian Quality Standard especially $PM_{2.5}$ concentration. Based on long term data of API measurement, it was found that almost 99% of API calculation is based on particulate matter concentration (PM_{10}) only. With the inclusion of $PM_{2.5}$ measurement, it is expected that the concentration of $PM_{2.5}$ will dominate the final values of API calculated in Malaysia.

The calculation of API (Eq. 5.1) will use the formula suggested by USEPA based on Eq. 1.1.

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (X_P - BP_{Lo}) + I_{Lo} \qquad \text{(Eq. 5.1)}$$

Where I_p = the index for pollutant p

X_p = the rounded concentration of pollutant p

BP_{Hi} = the breakpoint that is greater than or equal to X_p

BP_{Lo} = the breakpoint that is less than or equal to X_p

I_{Hi} = the API value corresponding to BP_{Hi}

I_{Lo} = the API value corresponding to BP_{Lo}

5.1 Consideration to Choose Breakpoints for API Based on Malaysian Air Quality Standard

Breakpoints for each category as explained by USEPA (Table 1.2) are based on health impact of each pollutant to human being. The breakpoints for USEPA were set up with little higher concentration than the air quality standard suggested for each air pollutants. To suit our API calculation based on the new Malaysian Air quality Standard (Appendix 2), which differs from that of USEPA, breakpoints for upper concentration of moderate level for certain pollutants such O_3 and $PM_{2.5}$ need to be modified. However, as the standard for O_3 for Malaysia is 0.10 ppm, lower than 0.12 ppm suggested by USEPA, we therefore decided to maintain the original USEPA-AQI breakpoints for O_3 (moderate and unhealthy). This is because the Malaysian Standard for O_3 is still lower compare to the lower breakpoints for unhealthy level which is 0.125. The standard will be a good warning point for people to be aware of the unhealthy level of O_3 concentration in ambient air. For the other pollutants (PM_{10}, SO_2 and NO_2), the Malaysian Air Quality Standard are also below the lower breakpoints for unhealthy health effect suggested by USEPA. Therefore, for these three pollutants, we suggest Malaysian calculation for API to follow the concentration of breakpoints suggested by USEPA for upper moderate and lower unhealthy level.

The main issue regarding the calculation of API is the breakpoints for $PM_{2.5}$ which is an important pollutant for API calculation. Since $PM_{2.5}$ standard will be implemented in stages from 2015 (IT-1), 2018 (IT-2) and 2020 (IT-3), the calculation of API can follow the $PM_{2.5}$ standard when $PM_{2.5}$ expected to be measured by Malaysian Department of Environment in 2017. In this case, the breakpoints suggested for API calculation in 2017, 2018-2019 and beyond 2020 are suggested to be 75.5 $\mu g/m^3$, 50.5 $\mu g/m^3$ and 35.5 $\mu g/m^3$ respectively. These values are based on the standard of $PM_{2.5}$ which are 75 $\mu g/m^3$ (2015), 50 $\mu g/m^3$ (2018) and 35 $\mu g/m^3$ (2020) (Appendix 2). The implementation by stages will allow the DOE to monitor the results of API calculation using $PM_{2.5}$ until 2020 when the USEPA standard is similarly used by Malaysian DOE.

Based on the above argument, the breakpoints for API calculation based on the Malaysian Air Quality Standard 2015, 2018 and 2020 are presented in Table 5.1, 5.2 and 5.3. The breakpoints based on Malaysian Air Quality Standard 2020 (IT-3) will strictly follow the breakpoints suggested by USEPA.

Table 5.1 Breakpoints values for the API calculation suggested based on USEPA breakpoints and Malaysian Air quality Standard (IT-1 2015)

Category	AQI	Parameter Breakpoint						
Parameter		O_3 (ppm)	O_3 (ppm)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)
Averaging Time		8-h	1-h	24-h	24-h	8-h	1-h	1-h
Good	0-50	0.000-0.059	-	0-54	0.0-12.0	0.0-4.4	0.000-0.035	0.000-0.053
Moderate	51-100	0.060-0.075	-	55-154	12.1-75.4	4.5-9.4	0.036-0.075	0.054-0.100
Unhealthy for Sensitive Groups	101-150	0.076-0.095	0.125-0.164	155-254	(75.5-150.4)[3]	9.5-12.4	0.076-0.185	0.101-0.360
Unhealthy	151-200	0.096-0.115	0.165-0.204	255-354		12.5-15.4	(0.186-0.304)[4]	0.361-0.649
Very unhealthy	201-300	0.116-0.374	0.205-0.404	355-424	(150.5-250.4)[3]	15.5-30.4	(0.305-0.604)[4]	0.650-1.249
Hazardous	301-400	([2])	0.405-0.504	425-504	(250.5-350.4)[3]	30.5-40.4	(0.605-0.804)[4]	1.250-1.649
Hazardous	401-500	([2])	0.505-0.604	505-604	(350.5-500.4)[3]	40.5-50.4	(0.805-1.004)[4]	1.650-2.049

[1]Areas are required to report the API based on 8-h ozone values. However, there are areas where an API based on 1-h ozone values would be more protective. In these cases the index for both the 8-h and the 1-h ozone values may be calculated and the maximum API reported.
[2]8-h O_3 values do not define higher AQI values (≥ 301). AQI values of 301 or higher are calculated with 1- h O_3 concentrations.
[3]If a different SHL for $PM_{2.5}$ is promulgated, these numbers will change accordingly.
[4]1-h SO_2 values do not define higher AQI values (≥ 200). AQI values of 200 or greater are calculated with 24-h SO_2 concentrations.

Table 5.2 Breakpoints values for the API calculation suggested based on USEPA breakpoints and Malaysian Air quality Standard (IT-2 2018)

Category	AQI	Parameter Breakpoint						
Parameter		O_3 (ppm)	O_3 (ppm)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)
Averaging Time		8-h	1-h	24-h	24-h	8-h	1-h	1-h
Good	0-50	0.000-0.059	-	0-54	0.0-12.0	0.0-4.4	0.000-0.035	0.000-0.053
Moderate	51-100	0.060-0.075	-	55-154	12.1-50.4	4.5-9.4	0.036-0.075	0.054-0.100
Unhealthy for Sensitive Groups	101-150	0.076-0.095	0.125-0.164	155-254	50.5-55.4	9.5-12.4	0.076-0.185	0.101-0.360
Unhealthy	151-200	0.096-0.115	0.165-0.204	255-354	(55.5-150.4)[3]	12.5-15.4	(0.186-0.304)[4]	0.361-0.649
Very unhealthy	201-300	0.116-0.374	0.205-0.404	355-424	(150.5-250.4)[3]	15.5-30.4	(0.305-0.604)[4]	0.650-1.249
Hazardous	301-400	([2])	0.405-0.504	425-504	(250.5-350.4)[3]	30.5-40.4	(0.605-0.804)[4]	1.250-1.649
Hazardous	401-500	([2])	0.505-0.604	505-604	(350.5-500.4)[3]	40.5-50.4	(0.805-1.004)[4]	1.650-2.049

[1]Areas are required to report the API based on 8-h ozone values. However, there are areas where an API based on 1-h ozone values would be more protective. In these cases the index for both the 8-h and the 1-h ozone values may be calculated and the maximum API reported.
[2]8-h O_3 values do not define higher AQI values (≥ 301). AQI values of 301 or higher are calculated with 1- h O_3 concentrations.
[3]If a different SHL for $PM_{2.5}$ is promulgated, these numbers will change accordingly.
[4]1-h SO_2 values do not define higher AQI values (≥ 200). AQI values of 200 or greater are calculated with 24-h SO_2 concentrations.

Table 5.3 Breakpoints values for the API calculation suggested based on USEPA breakpoints and Malaysian Air quality Standard (IT-3 2020)

Category	AQI	Parameter Breakpoint						
Parameter		O_3 (ppm)	O_3 (ppm)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)
Averaging Time		8-h	1-h	24-h	24-h	8-h	1-h	1-h
Good	0-50	0.000-0.059	-	0-54	0.0-12.0	0.0-4.4	0.000-0.035	0.000-0.053
Moderate	51-100	0.060-0.075	-	55-154	12.1-35.4	4.5-9.4	0.036-0.075	0.054-0.100
Unhealthy for Sensitive Groups	101-150	0.076-0.095	0.125-0.164	155-254	35.5-55.4	9.5-12.4	0.076-0.185	0.101-0.360
Unhealthy	151-200	0.096-0.115	0.165-0.204	255-354	(55.5-150.4)[3]	12.5-15.4	(0.186-0.304)[4]	0.361-0.649
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[1]Areas are required to report the API based on 8-h ozone values. However, there are areas where an API based on 1-h ozone values would be more protective. In these cases the index for both the 8-h and the 1-h ozone values may be calculated and the maximum API reported.
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[3]If a different SHL for $PM_{2.5}$ is promulgated, these numbers will change accordingly.
[4]1-h SO_2 values do not define higher AQI values (≥ 200). AQI values of 200 or greater are calculated with 24-h SO_2 concentrations.

5.2 API Calculation Formula

Base on the USEPA formula for calculation of API (Eq. 5.1) and breakpoints suggested for Malaysian Air Pollutant Index based on the new Malaysian Air Quality Standard (Table 5.1, 5.2 and 5.3) the equation for calculation of API for each pollutant are summarised in Table 5.4 until 5.9.

Table 5.4 Summary table for Ozone API index calculation based on USEPA formula

API range	Breakpoint of concentration	Equation for API
X =O_3 (8 h average, unit: ppm)		
0-50	0.000 < X < 0.059	$API = \left(\frac{50-0}{0.059-0.000}\right) \times (X - 0.000) + 0$
51-100	0.060 ≤ X ≤ 0.075	$API = \left(\frac{100-51}{0.075-0.060}\right) \times (X - 0.060) + 51$
101-150	0.076 ≤ X ≤ 0.095	$API = \left(\frac{150-101}{0.095-0.076}\right) \times (X - 0.076) + 101$
151-200	0.096 ≤ X ≤ 0.115	$API = \left(\frac{200-151}{0.115-0.096}\right) \times (X - 0.096) + 151$
201-300	0.116 ≤ X ≤ 0.374	$API = \left(\frac{300-201}{0.374-0.116}\right) \times (X - 0.116) + 201$
0.405 ≤ X ≤ 0.604		For the API for 8-hr O_3 conc., 0.116 [8-hr] - 0.404 [1-h] falls in API 201-300. In the same time, under the category API >301 for 8-hr O_3, 1-h conc. of O_3 is considered instead for the API, i.e. 0.405 [1-h] - 0.604 [1-h].
X =O_3 (1 h average, unit: ppm)		
101-150	0.125 ≤ X ≤ 0.164	$API = \left(\frac{150-101}{0.164-0.125}\right) \times (X - 0.125) + 101$
151-200	0.165 ≤ X ≤ 0.204	$API = \left(\frac{200-151}{0.204-0.165}\right) \times (X - 0.165) + 151$
201-300	0.205 ≤ X ≤ 0.404	$API = \left(\frac{300-201}{0.404-0.205}\right) \times (X - 0.205) + 201$
301-400	0.405 ≤ X ≤ 0.504	$API = \left(\frac{400-301}{0.504-0.405}\right) \times (X - 0.405) + 301$
401-500	0.505 ≤ X ≤ 0.604	$API = \left(\frac{500-401}{0.604-0.505}\right) \times (X - 0.505) + 401$

Table 5.5 Summary table for PM_{10} API index calculation based on USEPA formula

API range	Breakpoint of concentration	Equation for API
X =PM_{10} (24 h average, unit: µg/m^3)		
0-50	0 < X < 54	$API = \left(\frac{50-0}{54-0}\right) \times (X-0) + 0$
51-100	55 ≤ X ≤ 154	$API = \left(\frac{100-51}{154-55}\right) \times (X-55) + 51$
101-150	155 ≤ X ≤ 254	$API = \left(\frac{150-101}{254-155}\right) \times (X-155) + 101$
151-200	255 ≤ X ≤ 354	$API = \left(\frac{200-151}{354-255}\right) \times (X-255) + 151$
201-300	355 ≤ X ≤ 424	$API = \left(\frac{300-201}{424-355}\right) \times (X-355) + 201$
301-400	425 ≤ X ≤ 504	$API = \left(\frac{400-301}{504-425}\right) \times (X-425) + 301$
401-500	505 ≤ X ≤ 604	$API = \left(\frac{500-401}{604-505}\right) \times (X-505) + 401$

Table 5.6a Summary table for $PM_{2.5}$ API index (IT1 2015) calculation modified from USEPA formula

API	Breakpoint of concentration	Equation for API
X = $PM_{2.5}$ (24 h average, unit: µg/m^3)		
0-50	0 < X < 12.0	$API = \left(\frac{50-0}{12.0-0}\right) \times (X-0) + 0$
51-100	12.1 ≤ X ≤ 75.4	$API = \left(\frac{100-51}{75.4-12.1}\right) \times (X-12.1) + 51$
101-200	75.5 ≤ X ≤ 150.4	$API = \left(\frac{200-101}{150.4-75.5}\right) \times (X-75.5) + 101$
201-300	150.5 ≤ X ≤ 250.4	$API = \left(\frac{300-201}{250.4-150.5}\right) \times (X-150.5) + 201$
301-400	250.5 ≤ X ≤ 350.4	$API = \left(\frac{400-301}{350.4-250.5}\right) \times (X-250.5) + 301$
401-500	350.5 ≤ X ≤ 500.4	$API = \left(\frac{500-401}{500.4-350.5}\right) \times (X-350.5) + 401$

Table 5.6b Summary table for $PM_{2.5}$ API index (IT-2 2018) calculation modified from USEPA formula

API	Breakpoint of concentration	Equation for API
X = $PM_{2.5}$ (24 h average, unit: µg/m^3)		
0-50	0 < X < 12.0	$API = \left(\frac{50-0}{12.0-0}\right) \times (X-0) + 0$
51-100	12.1 ≤ X ≤ 50.4	$API = \left(\frac{100-51}{50.4-12.1}\right) \times (X-12.1) + 51$
101-150	50.5 ≤ X ≤ 55.4	$API = \left(\frac{150-101}{55.4-50.5}\right) \times (X-50.5) + 101$
151-200	55.5 ≤ X ≤ 150.4	$API = \left(\frac{200-151}{150.4-55.5}\right) \times (X-55.5) + 151$
201-300	150.5 ≤ X ≤ 250.4	$API = \left(\frac{300-201}{250.4-150.5}\right) \times (X-150.5) + 201$
301-400	250.5 ≤ X ≤ 350.4	$API = \left(\frac{400-301}{350.4-250.5}\right) \times (X-250.5) + 301$
401-500	350.5 ≤ X ≤ 500.4	$API = \left(\frac{500-401}{500.4-350.5}\right) \times (X-350.5) + 401$

Table 5.6c Summary table for $PM_{2.5}$ API index calculation based on USEPA formula and Malaysian Air Quality Standard for $PM_{2.5}$ (IT-3 2020)

API	Breakpoint of concentration	Equation for API
X = $PM_{2.5}$ (24 h average, unit: µg/m^3)		
0-50	0 < X < 12.0	$API = \left(\frac{50-0}{12.0-0}\right) \times (X-0) + 0$
51-100	12.1 ≤ X ≤ 35.4	$API = \left(\frac{100-51}{35.4-12.1}\right) \times (X-12.1) + 51$
101-150	35.5 ≤ X ≤ 55.4	$API = \left(\frac{150-101}{55.4-35.5}\right) \times (X-35.5) + 101$
151-200	55.5 ≤ X ≤ 150.4	$API = \left(\frac{200-151}{150.4-55.5}\right) \times (X-55.5) + 151$
201-300	150.5 ≤ X ≤ 250.4	$API = \left(\frac{300-201}{250.4-150.5}\right) \times (X-150.5) + 201$
301-400	250.5 ≤ X ≤ 350.4	$API = \left(\frac{400-301}{350.4-250.5}\right) \times (X-250.5) + 301$
401-500	350.5 ≤ X ≤ 500.4	$API = \left(\frac{500-401}{500.4-350.5}\right) \times (X-350.5) + 401$

Table 5.7 Summary table for CO API index calculation based on USEPA formula

API	Breakpoint of concentration	Equation for API
X = CO (8 h average, unit: ppm)		
0-50	0 < X < 4.4	$API = \left(\frac{50-0}{4.4-0}\right) \times (X-0) + 0$
51-100	4.5 ≤ X ≤ 9.4	$API = \left(\frac{100-51}{9.4-4.5}\right) \times (X-4.5) + 51$
101-150	9.5 ≤ X ≤ 12.4	$API = \left(\frac{150-101}{12.4-9.5}\right) \times (X-9.5) + 101$
151-200	12.5 ≤ X ≤ 15.4	$API = \left(\frac{200-151}{15.4-12.5}\right) \times (X-12.5) + 151$
201-300	15.5 ≤ X ≤ 30.4	$API = \left(\frac{300-201}{30.4-15.5}\right) \times (X-15.5) + 201$
301-400	30.5 ≤ X ≤ 40.4	$API = \left(\frac{400-301}{40.4-30.5}\right) \times (X-30.5) + 301$
401-500	40.5 ≤ X ≤ 50.4	$API = \left(\frac{500-401}{50.4-40.5}\right) \times (X-40.5) + 401$

Table 5.8 Summary table for SO_2 API index calculation based on USEPA formula

API	Breakpoint of concentration	Equation for API
X = SO_2 (1 h average, unit: ppm)		
0-50	0.000 < X < 0.035	$API = \left(\frac{50-0}{0.035-0}\right) \times (X-0) + 0$
51-100	0.036 ≤ X ≤ 0.075	$API = \left(\frac{100-51}{0.075-0.036}\right) \times (X-0.036) + 51$
101-150	0.076 ≤ X ≤ 0.185	$API = \left(\frac{150-101}{0.185-0.076}\right) \times (X-0.076) + 101$
151-200	0.186 ⩽ X ⩽ 0.304	$API = \left(\frac{200-151}{0.304-0.186}\right) \times (X-0.186) + 151$ (a) 24-h SO_2, the conc. is lower than 0.186, then we use 1-h SO_2 (b) Or If you have a daily max 1-h SO_2 concentration below 0.305 ppm, then use 1-h breakpoints in Table XX to calculate the AQI value
201-300	0.305 ≤ X ≤ 0.604	$API = \left(\frac{300-201}{0.604-0.305}\right) \times (X-0.305) + 201$ (a) If you have a 24-h average SO_2 concentration greater than or equal to 0.305 ppm, then use 24-h the breakpoints in Table XX to calculate the AQI value. (b) On rare occasions, you could have a day where the daily max 1-h concentration is at or above 0.305 ppm but when you try to use the 24-h average to calculate the AQI value, you find that the 24-h concentration is not above 0.305 ppm. If this happens, use 200 for the lower and upper AQI breakpoints (ILo and IHi) in Eq. 1 to calculate the AQI value based on the daily max 1-h value.
301-400	0.605 ≤ X ≤ 0.804	$API = \left(\frac{400-301}{0.804-0.605}\right) \times (X-0.605) + 301$
401-500	0.805 ≤ X ≤ 1.004	$API = \left(\frac{500-401}{1.004-0.805}\right) \times (X-0.805) + 401$

Table 5.9 Summary table for NO_2 API index calculation based on USEPA formula

API	Breakpoint of concentration	Equation for API
X = NO_2 (1 h average, unit: ppm)		
0-50	0.000 < X < 0.053	$API = \left(\frac{50-0}{0.053-0.000}\right) \times (X - 0.000) + 0$
51-100	0.054 ≤ X ≤ 0.100	$API = \left(\frac{100-51}{0.100-0.054}\right) \times (X - 0.054) + 51$
101-150	0.101 ≤ X ≤ 0.360	$API = \left(\frac{150-101}{0.360-0.101}\right) \times (X - 0.101) + 101$
151-200	0.361 ≤ X ≤ 0.649	$API = \left(\frac{200-151}{0.649-0.361}\right) \times (X - 0.361) + 101$
201-300	0.650 ≤ X ≤ 1.249	$API = \left(\frac{300-201}{1.249-0.650}\right) \times (X - 0.650) + 201$
301-400	1.250 ≤ X ≤ 1.649	$API = \left(\frac{400-301}{1.649-1.250}\right) \times (X - 1.250) + 301$
401-500	1.650 ≤ X ≤ 2.049	$API = \left(\frac{500-401}{2.049-1.650}\right) \times (X - 1.650) + 401$

The summary for the new API calculation for all pollutants are shown in Table 5.10 until 5.15

Table 5.10 Summary of API calculation factor for Ozone based on USEPA formula

API range	Breakpoint of concentration	Equation for API
X =O_3 (8 h average, unit: ppm)		
0-50	0.000 < X < 0.059	$API = 847.4576 \times X$
51-100	0.060 ≤ X ≤ 0.075	$API = 3266.6667 \times (X - 0.060) + 51$
101-150	0.076 ≤ X ≤ 0.095	$API = 2450.0000 \times (X - 0.076) + 101$
151-200	0.096 ≤ X ≤ 0.115	$API = 2578.9474 \times (X - 0.096) + 151$
201-300	0.116 ≤ X ≤ 0.374	$API = 383.7209 \times (X - 0.116) + 201$
0.405 ≤ X ≤ 0.604		For the API for 8-hr O_3 conc., 0.116 [8-hr] - 0.404 [1-h] falls in API 201-300. In the same time, under the category API >301 for 8-hr O_3, 1-h conc. of O_3 is considered instead for the API, i.e. 0.405 [1-h] - 0.604 [1-h].
X =O_3 (1 h average, unit: ppm)		
101-150	0.125 ≤ X ≤ 0.164	$API = 1256.4103 \times (X - 0.125) + 101$
151-200	0.165 ≤ X ≤ 0.204	$API = 1256.4103 \times (X - 0.165) + 151$
201-300	0.205 ≤ X ≤ 0.404	$API = 497.4874 \times (X - 0.205) + 201$
301-400	0.405 ≤ X ≤ 0.504	$API = 1000 \times (X - 0.405) + 301$
401-500	0.505 ≤ X ≤ 0.604	$API = 1000 \times (X - 0.505) + 401$

Table 5.11 Summary of API calculation factor for PM_{10} based on USEPA formula

API range	Breakpoint of concentration	Equation for API
X =PM_{10} (24 h average, unit: µg/m^3)		
0-50	0 < X < 54	$API = 0.9259 \times X$
51-100	55 ≤ X ≤ 154	$API = 0.4949 \times (X - 55) + 51$
101-150	155 ≤ X ≤ 254	$API = 0.4949 \times (X - 155) + 101$
151-200	255 ≤ X ≤ 354	$API = 0.4949 \times (X - 255) + 151$
201-300	355 ≤ X ≤ 424	$API = 1.4348 \times (X - 355) + 201$
301-400	425 ≤ X ≤ 504	$API = 1.2532 \times (X - 425) + 301$
401-500	505 ≤ X ≤ 604	$API = 1 \times (X - 505) + 401$

Table 5.12a Summary of API calculation factor $PM_{2.5}$ (IT-1 2015) modified USEPA formula

API	Breakpoint of concentration	Equation for API
X = $PM_{2.5}$ (24 h average, unit: µg/m^3)		
0-50	0 < X < 12.0	$API = 4.1667 \times X$
51-100	12.1 ≤ X ≤ 75.4	$API = 0.7741 \times (X - 12.1) + 51$
101-200	75.5 ≤ X ≤ 150.4	$API = 1.3218 \times (X - 75.5) + 101$
201-300	150.5 ≤ X ≤ 250.4	$API = 0.9909 \times (X - 150.5) + 201$
301-400	250.5 ≤ X ≤ 350.4	$API = 0.9909 \times (X - 250.5) + 301$
401-500	350.5 ≤ X ≤ 500.4	$API = 0.6604 \times (X - 350.5) + 401$

Table 5.12b Summary of API calculation factor $PM_{2.5}$ (IT-2 2018) modified USEPA formula

API	Breakpoint of concentration	Equation for API
X = $PM_{2.5}$ (24 h average, unit: µg/m^3)		
0-50	0 < X < 12.0	$API = 4.1667 \times X$
51-100	12.1 ≤ X ≤ 50.4	$API = 1.2794 \times (X - 12.1) + 51$
101-150	50.5 ≤ X ≤ 55.4	$API = 10 \times (X - 50.5) + 101$
151-200	55.5 ≤ X ≤ 150.4	$API = 0.5163 \times (X - 55.5) + 151$
201-300	150.5 ≤ X ≤ 250.4	$API = 0.9909 \times (X - 150.5) + 201$
301-400	250.5 ≤ X ≤ 350.4	$API = 0.9909 \times (X - 250.5) + 301$
401-500	350.5 ≤ X ≤ 500.4	$API = 0.6604 \times (X - 350.5) + 401$

Table 5.12c Summary of API calculation factor $PM_{2.5}$ (IT-3 2020) modified USEPA formula

API	Breakpoint of concentration	Equation for API
X = $PM_{2.5}$ (24 h average, unit: µg/m^3)		
0-50	0 < X < 12.0	$API = 4.1667 \times X$
51-100	12.1 ≤ X ≤ 35.4	$API = 2.1030 \times (X - 12.1) + 51$
101-150	35.5 ≤ X ≤ 55.4	$API = 2.4623 \times (X - 35.5) + 101$
151-200	55.5 ≤ X ≤ 150.4	$API = 0.5163 \times (X - 55.5) + 151$
201-300	150.5 ≤ X ≤ 250.4	$API = 0.9909 \times (X - 150.5) + 201$
301-400	250.5 ≤ X ≤ 350.4	$API = 0.9909 \times (X - 250.5) + 301$
401-500	350.5 ≤ X ≤ 500.4	$API = 0.6604 \times (X - 350.5) + 401$

Table 5.13 Summary of API calculation factor for CO based on USEPA formula

API	Breakpoint of concentration	Equation for API
X = CO (8 h average, unit: ppm)		
0-50	0 < X < 4.4	$API = 11.3636 \times X$
51-100	4.5 ⩽ X ⩽ 9.4	$API = 10 \times (X - 4.5) + 51$
101-150	9.5 ⩽ X ⩽ 12.4	$API = 16.8965 \times (X - 9.5) + 101$
151-200	12.5 ⩽ X ⩽ 15.4	$API = 16.8965 \times (X - 12.5) + 151$
201-300	15.5 ⩽ X ⩽ 30.4	$API = 6.6443 \times (X - 15.5) + 201$
301-400	30.5 ⩽ X ⩽ 40.4	$API = 10 \times (X - 30.5) + 301$
401-500	40.5 ⩽ X ⩽ 50.4	$API = 10 \times (X - 40.5) + 401$

Table 5.14 Summary of API calculation factor for SO_2 based on USEPA formula

API	Breakpoint of concentration	Equation for API
X = SO_2 (1 h average, unit: ppm)		
0-50	0.000 < X < 0.035	$API = 1428.5714 \times X$
51-100	0.036 ≤ X ≤ 0.075	$API = 1256.4103 \times (X - 0.036) + 51$
101-150	0.076 ≤ X ≤ 0.185	$API = 449.5413 \times (X - 0.076) + 101$
151-200	0.186 ⩽ X ⩽ 0.304	$API = 415.2542 \times (X - 0.186) + 151$ (a) 24-h SO_2, the conc. is lower than 0.186, then we use 1-h SO_2 (b) Or If you have a daily max 1-h SO_2 concentration below 0.305 ppm, then use 1-h breakpoints in Table XX to calculate the AQI value
201-300	0.305 ≤ X ≤ 0.604	$API = 331.1037 \times (X - 0.305) + 201$ (a) If you have a 24-h average SO_2 concentration greater than or equal to 0.305 ppm, then use 24-h the breakpoints in Table XX to calculate the AQI value. (b) On rare occasions, you could have a day where the daily max 1-h concentration is at or above 0.305 ppm but when you try to use the 24-h average to calculate the AQI value, you find that the 24-h concentration is not above 0.305 ppm. If this happens, use 200 for the lower and upper AQI breakpoints (ILo and IHi) in Eq. 1 to calculate the AQI value based on the daily max 1-h value.
301-400	0.605 ≤ X ≤ 0.804	$API = 497.4874 \times (X - 0.605) + 301$
401-500	0.805 ≤ X ≤ 1.004	$API = 497.4874 \times (X - 0.805) + 401$

Table 5.15 Summary of API calculation factor for NO_2 based on USEPA formula

API	Breakpoint of concentration	Equation for API
X = NO_2 (1 h average, unit: ppm)		
0-50	0.000 < X < 0.053	$API = 943.3962 \times X$
51-100	0.054 ≤ X ≤ 0.100	$API = 1065.2174 \times (X - 0.054) + 51$
101-150	0.101 ≤ X ≤ 0.360	$API = 189.1892 \times (X - 0.101) + 101$
151-200	0.361 ≤ X ≤ 0.649	$API = 170.1389 \times (X - 0.361) + 151$
201-300	0.650 ≤ X ≤ 1.249	$API = 165.2755 \times (X - 0.650) + 201$
301-400	1.250 ≤ X ≤ 1.649	$API = 248.1203 \times (X - 1.250) + 301$
401-500	1.650 ≤ X ≤ 2.049	$API = 248.1203 \times (X - 1.650) + 401$

6.0 Comparison between Current Malaysian Air Pollution Index and New API modified from USEPA Calculation

Difference in API values between calculation using API calculation formula currently used by Malaysian Department of Environment and modified USEPA calculation for five major air pollutants (PM_{10}, SO_2, CO, O_3 and NO_2) are shown in Figure 6.1. With the exception of NO_2, we found that overall the results were similar. The small differences arise between both calculations approaches are due to the fixed coefficients in the formula used. For NO_2 calculations, the difference is due to the definition of risk by USEPA on NO_2, whereby hourly NO_2 can only generate an API only above a value of 200, while for hourly O_3 it's the higher breakpoint suggested by the new API discussed in Section 5.1.

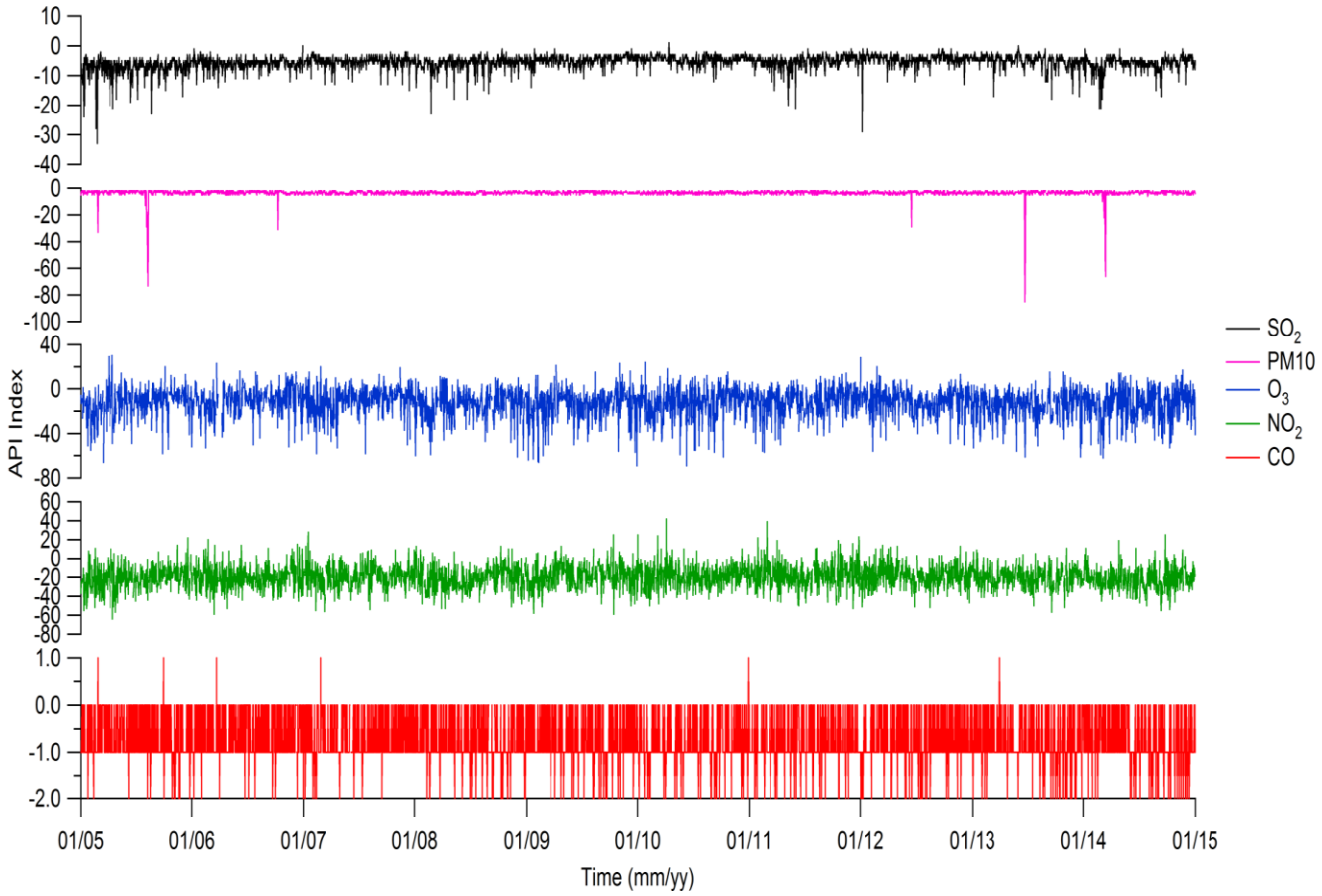

Figure 6.1 Difference between Current API index values and the suggested API calculated based on USEPA-AQI at Petaling Jaya station when calculated using USEPA formula and MY-API formula for five pollutants.

7.0 API Calculation using $PM_{2.5}$ Compare to PM_{10}

As the Malaysian Environment Department will soon be taking into consideration the concentration of $PM_{2.5}$ in its API calculation (based on $PM_{2.5}$'s breakpoints for 2015, 2018 and 2020) using $PM_{2.5}$ concentration recorded in year 2013 at several selected stations in Malaysia by DOE, we compared the $PM_{2.5}$ sub-index calculated using the proposed new API calculation of Malaysia to that of PM_{10} at 8 selected stations. The results are shown in Figure 7.1 and 7.2. As the concentration of $PM_{2.5}$ was recorded by DOE using continuous $PM_{2.5}$ sampler, the concentration of $PM_{2.5}$ recorded in several stations are generally non-continuous and will be experiencing some unrealistic spikes or drops when the instrument was turned either on or off. The results indicate that the API will be far higher (around 41.1%) if $PM_{2.5}$ is included for API calculation even using 2015 (IT-1) breakpoints. The API values using $PM_{2.5}$ breakpoints based on 2018 (IT-2) and 2020 (IT-3) standard are significanylu higher (more than 49.7 % and 60.2 %) compared to API calculated using PM_{10} (Table 7.1).

Table 7.1. The average percentage (%) differences between PM_{10} and $PM_{2.5}$ sub-index of different targets (2015, 2018 and 2020), and between $PM_{2.5}$ sub-index of different targets.

	PM_{10}	$PM_{2.5}$ (2015)	$PM_{2.5}$ (2018)
$PM_{2.5}$ (2015)	41.1		
$PM_{2.5}$ (2018)	49.7	6.8	
$PM_{2.5}$ (2020)	60.2	15.1	7.3

7.1 Comparison of API Calculated using Different $PM_{2.5}$ Breakpoints Based on Different Standard

The comparison of API calculation using different breakpoints of moderate-unhealthy level based on $PM_{2.5}$ standard 2015 (IT-1), 2018 (IT-2) and 2020 (IT-3) are shown in Figure 7.3 to 7.8. The difference in API based on 2015 $PM_{2.5}$ standard was found to range from 0% to around 60% compared to the API based on $PM_{2.5}$ standard from 2018 and 2020. The average difference between $PM_{2.5}$ standard in 2015 and $PM_{2.5}$ standard starting from 2018 and 2020 are 6.8% and 15.1% respectively (Table 7.1). The difference between $PM_{2.5}$ standard starting from 2018 to $PM_{2.5}$ standard starting from 2020 can be as high as 20% with an average of around 7.3%.

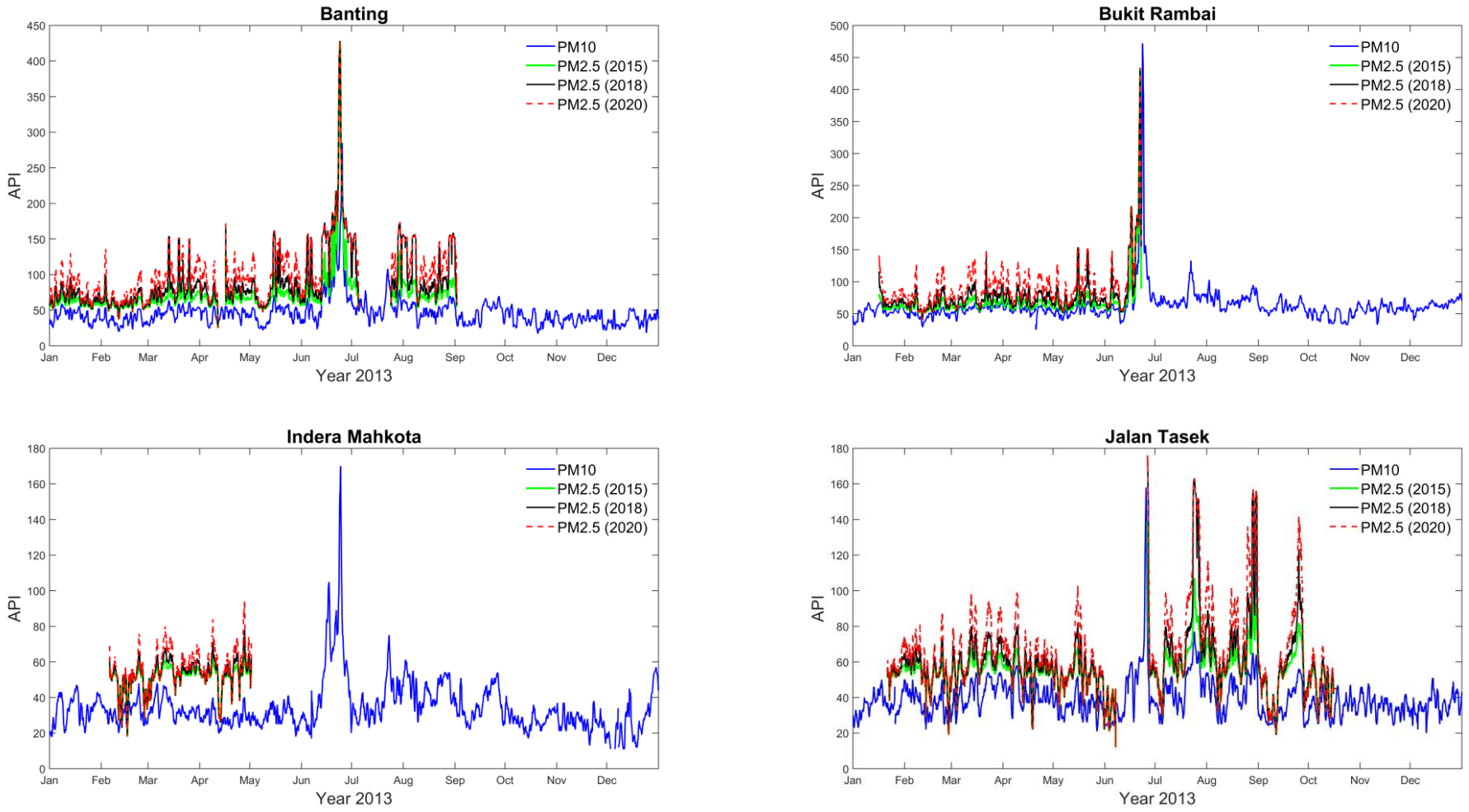

Figure 7.1 Comparison of API calculation using PM_{10} and $PM_{2.5}$ at station Banting, Bukit Rambai, Indera Mahkota and Jalan Tasek.

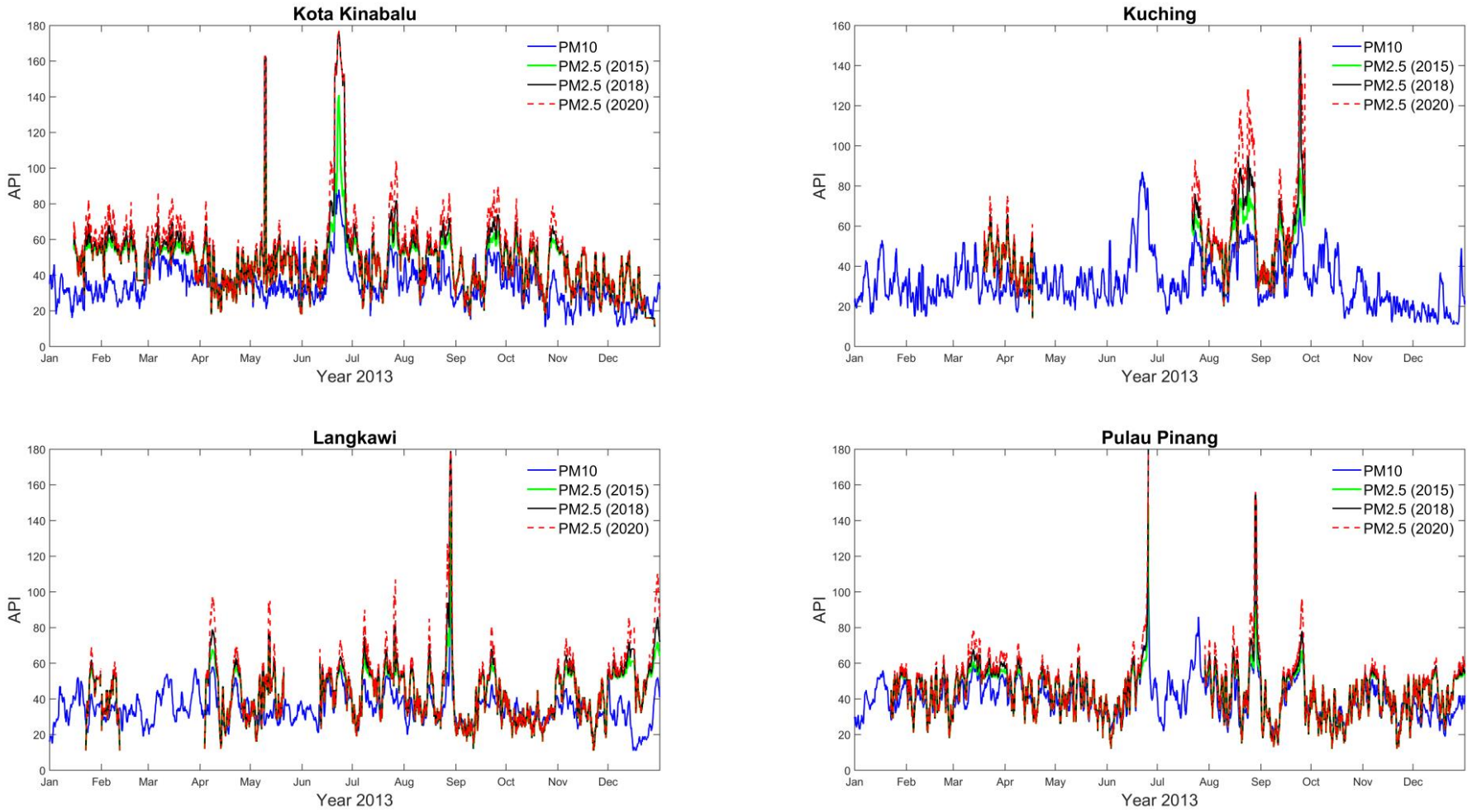

Figure 7.2 Comparison of API calculation using PM_{10} and $PM_{2.5}$ at station Kota Kinabalu, Kuching, Langkawi and Pulau Pinang

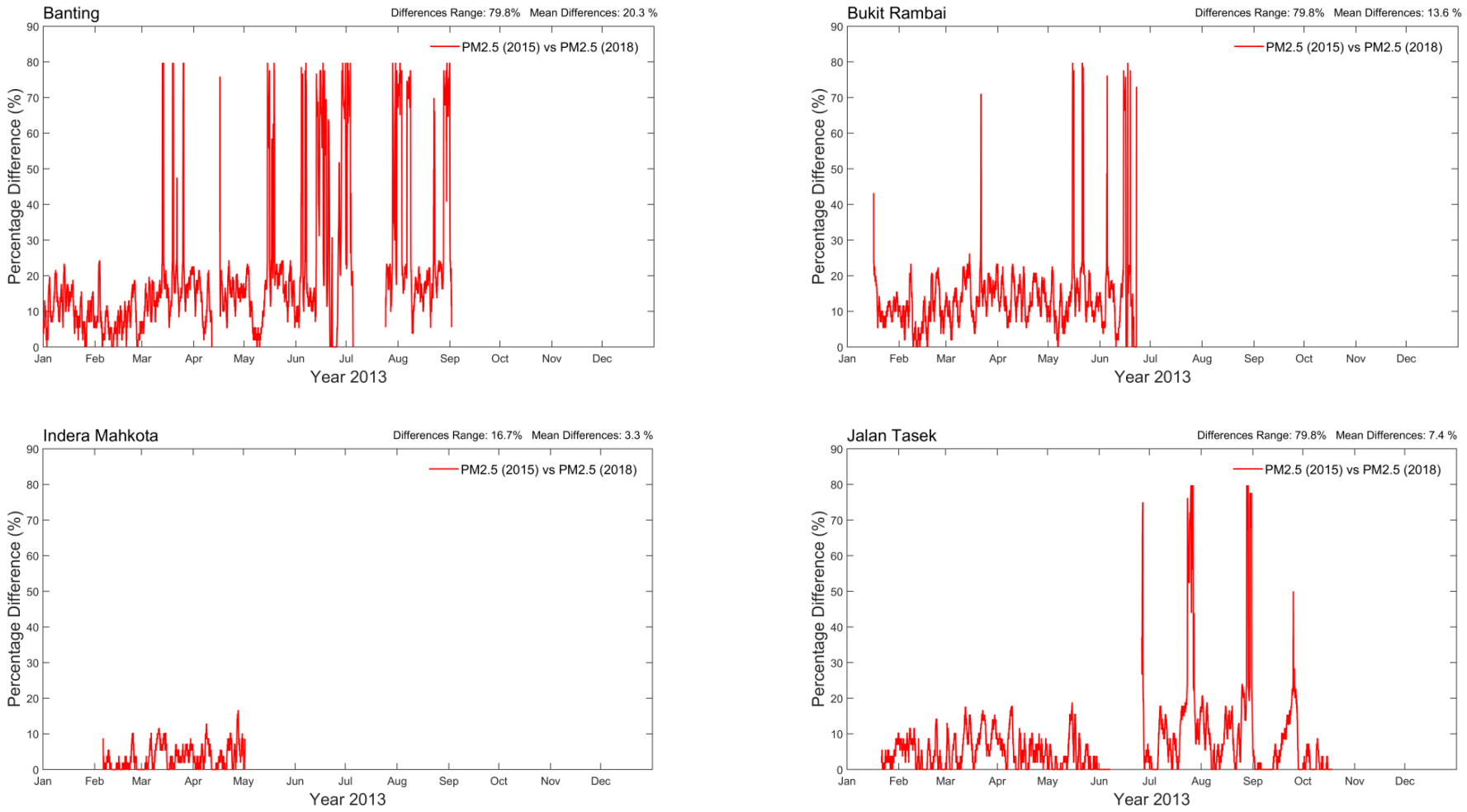

Figure 7.3 Different between API calculate using $PM_{2.5}$'s breakpoints for 2015 and 2018 at station Banting, Bukit Rambai, Indera Mahkota and Jalan Tasek

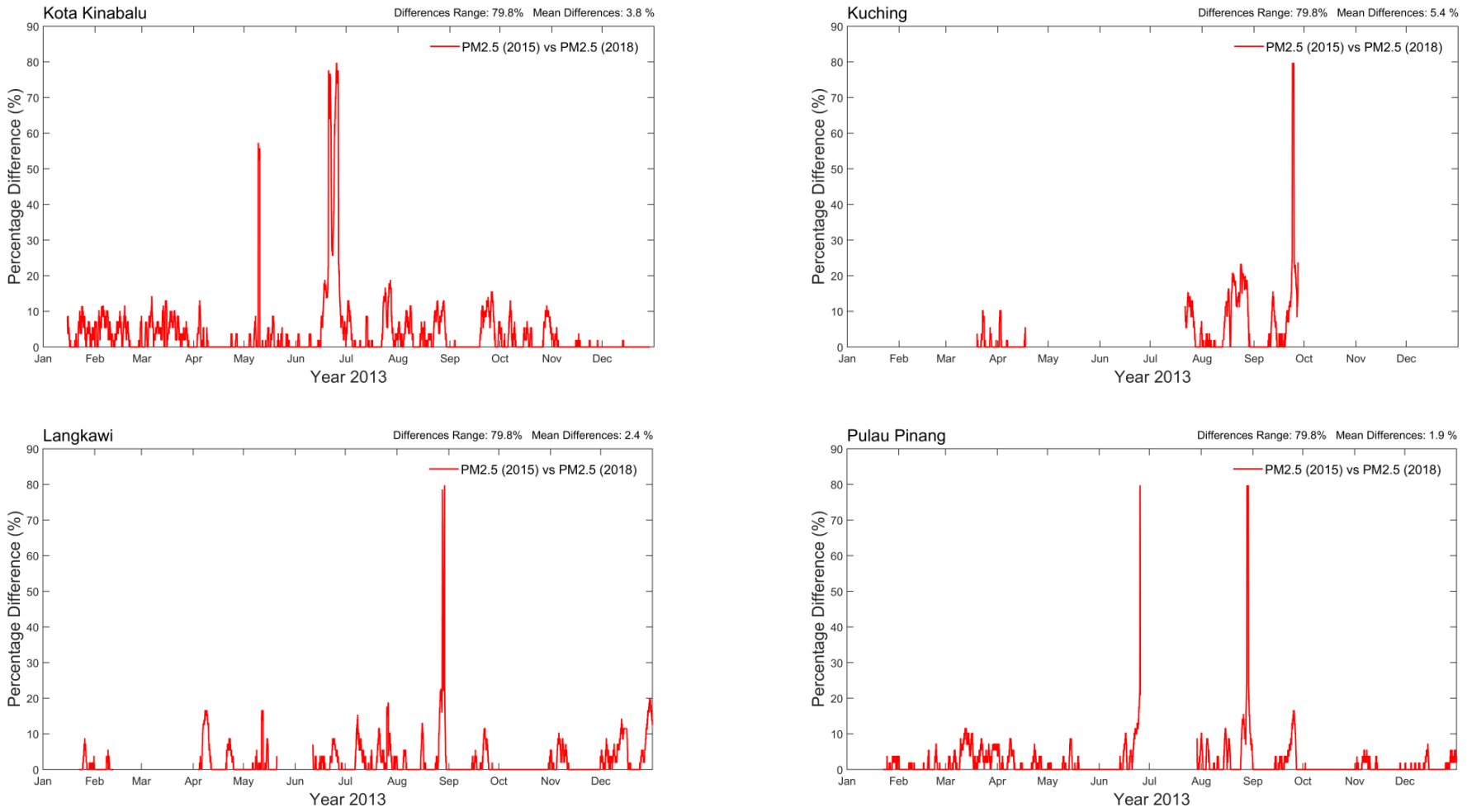

Figure 7.4 Different between API calculate using $PM_{2.5}$'s breakpoints for 2015 and 2018 at station Kota Kinabalu, Kuching, Langkawi and Pulau Pinang

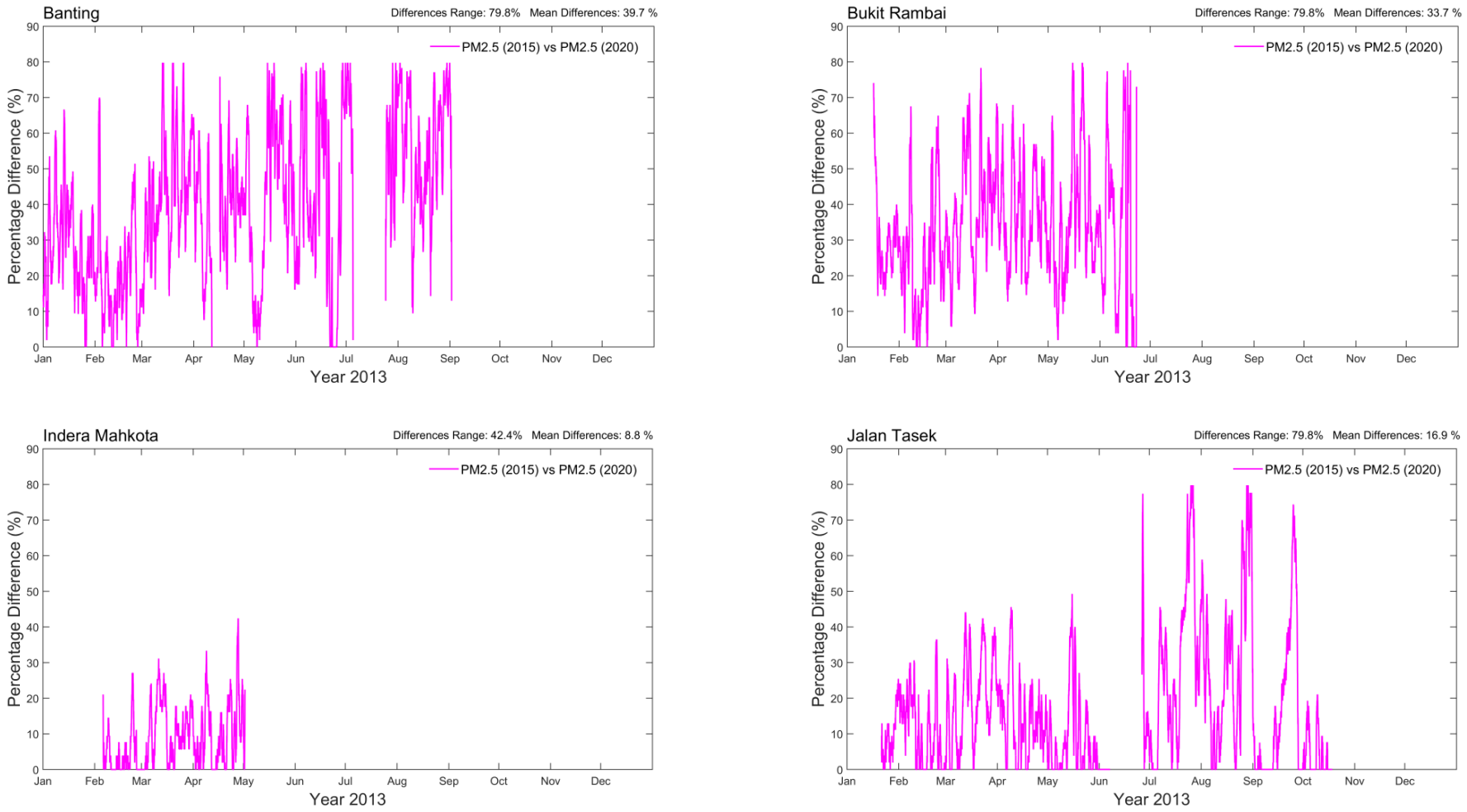

Figure 7.5 Different between API calculate using $PM_{2.5}$'s breakpoints for 2015 and 2020 at station Banting, Bukit Rambai, Indera Mahkota and Jalan Tasek

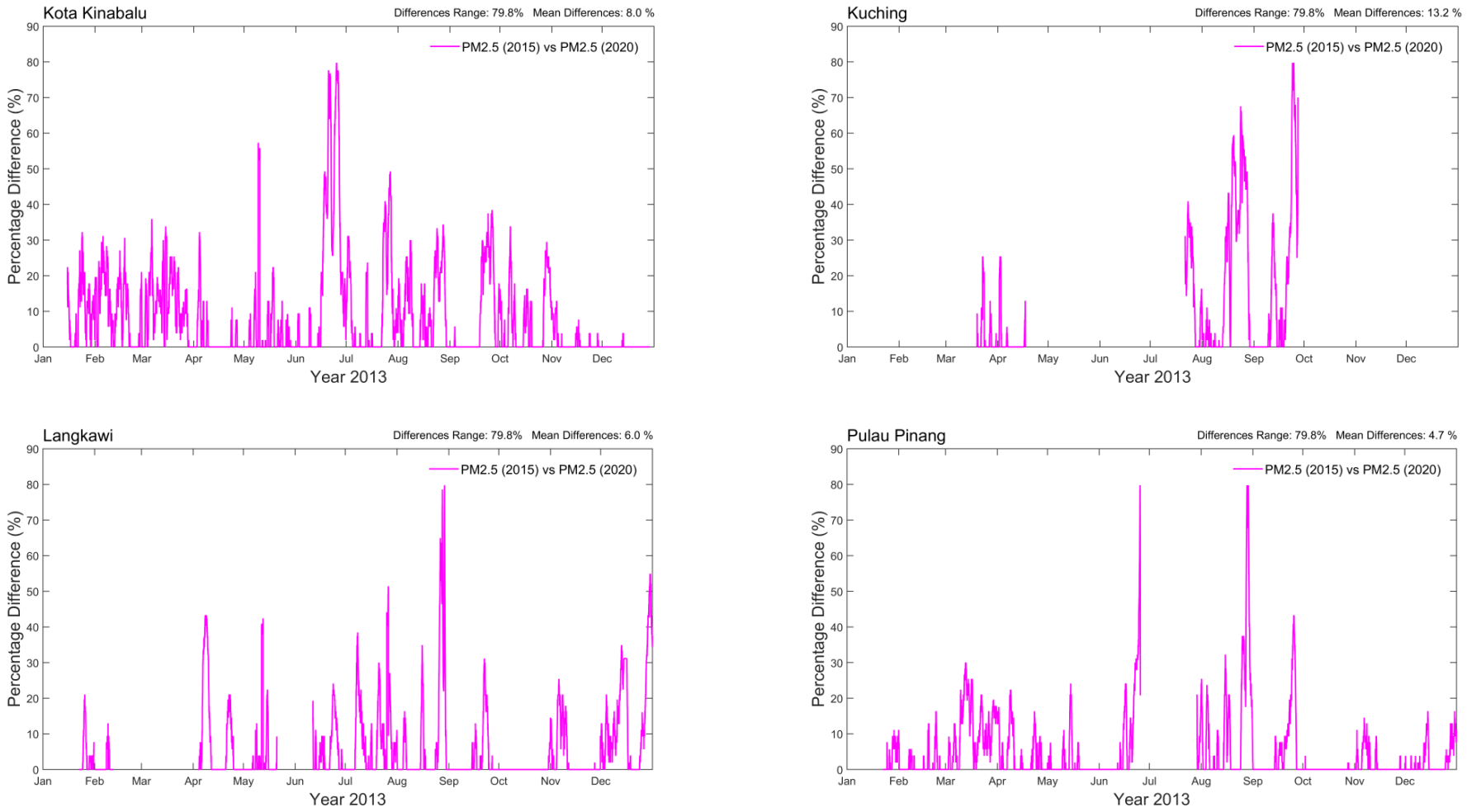

Figure 7.6 Different between API calculate using $PM_{2.5}$'s breakpoints for 2015 and 2020 at station Kota Kinabalu, Kuching, Langkawi and Pulau Pinang

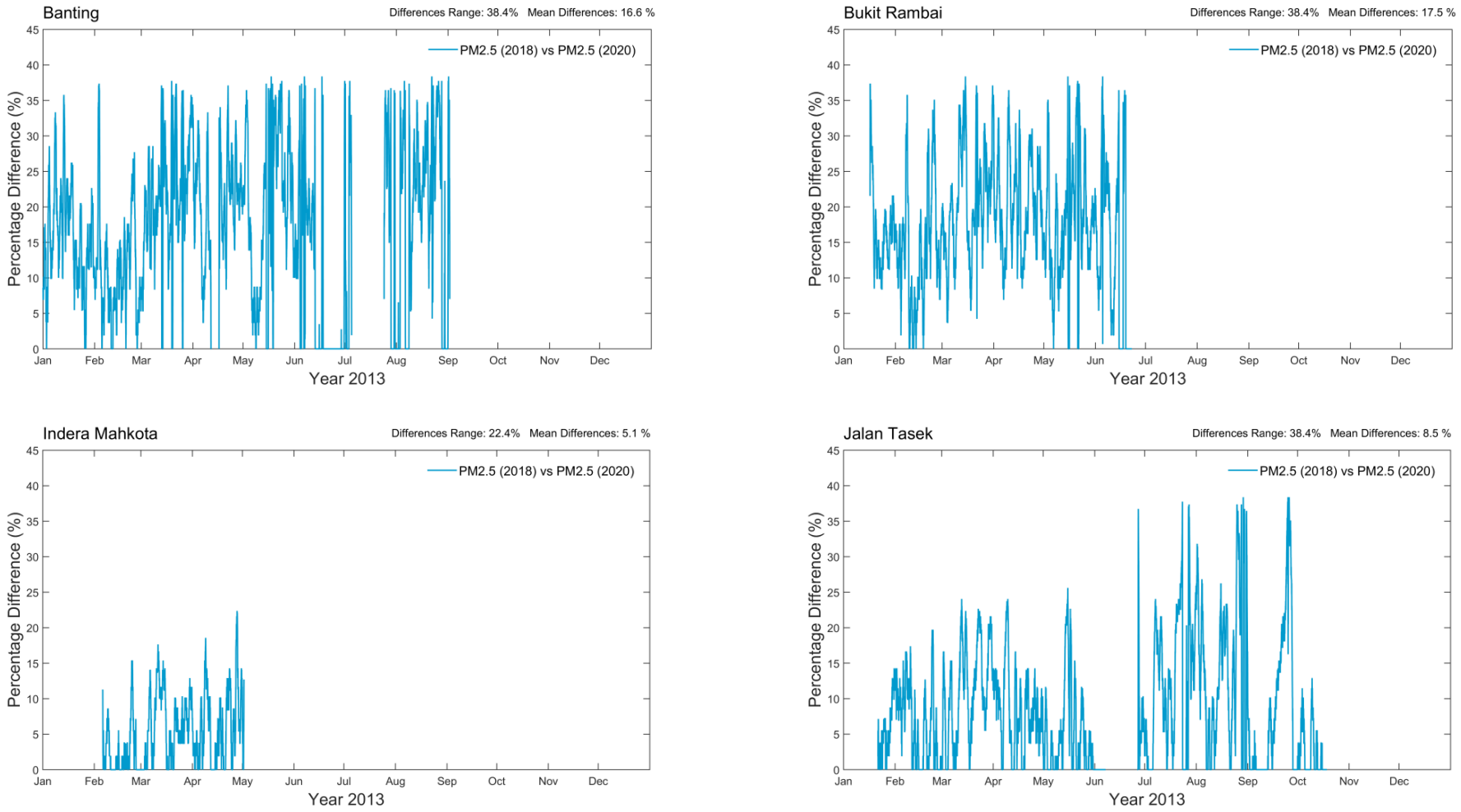

Figure 7.7 Different between API calculate using $PM_{2.5}$'s breakpoints for 2018 and 2020 at station Banting, Bukit Rambai, Indera Mahkota and Jalan Tasek

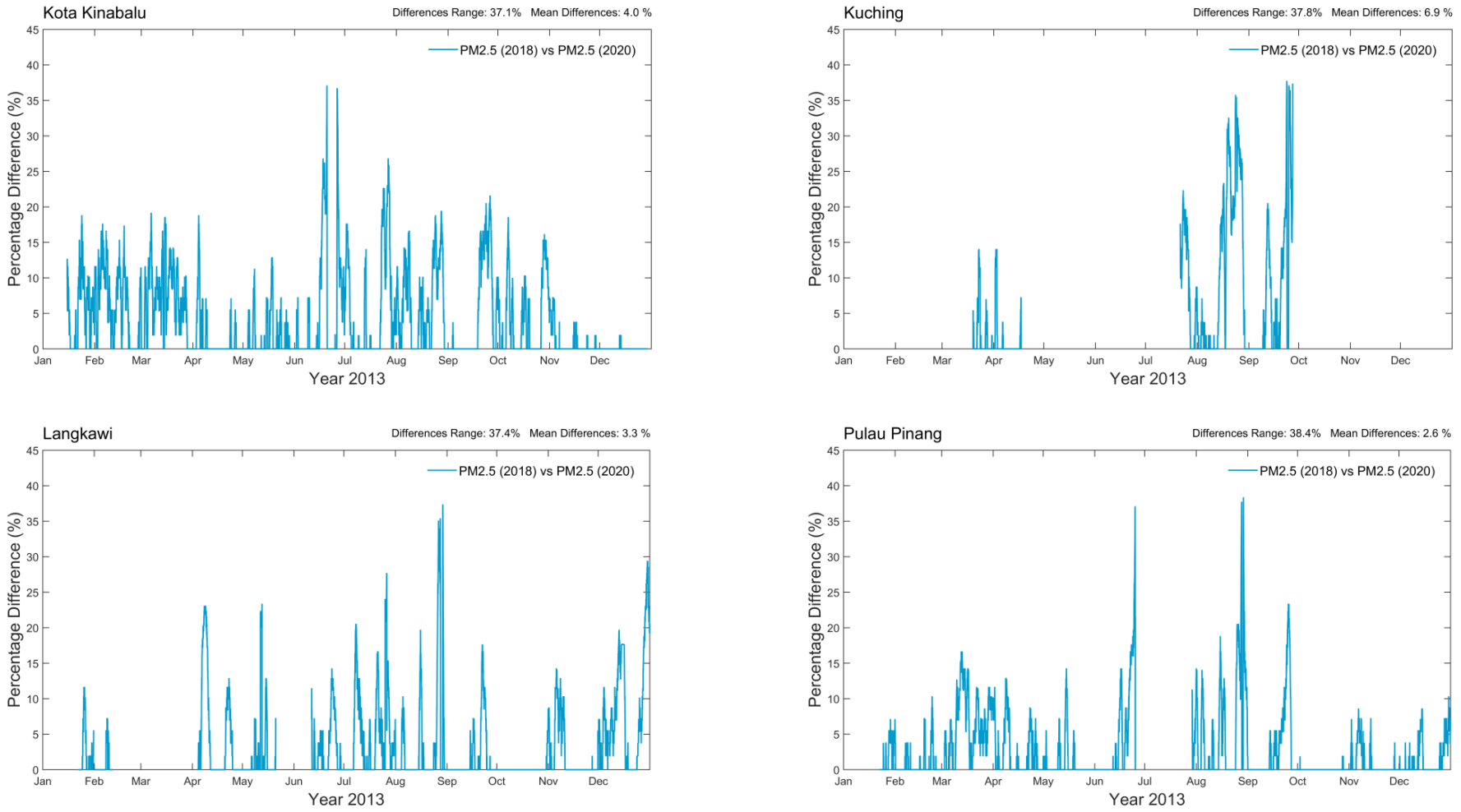

Figure 7.8 Different between API calculate using $PM_{2.5}$'s breakpoints for 2018 and 2020 at station Kota Kinabalu, Kuching, Langkawi and Pulau Pinang

8.0 API Reporting

In many cases API was reported in a map showing all air quality monitoring stations available. Report on API usually consists of below information:

1. The reporting area (s),
2. The reporting period,
3. The critical pollutant,
4. The API,
5. The category descriptor and, if reported in a colour format, the associated colour.

The common descriptor and colour suggested for Malaysia API modified from USEPA are shown in Table 8.1.

Table 8.1: Common descriptor and colour suggested for Malaysian API

Air Pollutant Index (API) Values	Levels of Health Concern	Colors
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Orange
201 to 300	Very Unhealthy	Red
>300	Hazardous	Maroon

It is important to inform the public when the API is above 100 (Table 8.2). Whenever the API exceeds 100, reporting agencies should expand reporting to all major news media, and at a minimum, should include notification to the media with the largest market coverage for the area in question.

Table 8.2: Pollutant specific sensitive groups

When this pollutant has an index above100…	Report these Sensitive Group
Ozone	People with lung disease, children, older adults, and people who are active outdoors are the groups most at risk
$PM_{2.5}$	People with heart or lung disease, older adults, children, and people of lower socioeconomic status (SES) are the groups most at risk
PM_{10}	People with heart or lung disease, older adults, children, and people of lower socioeconomic status are the groups most at risk
CO	People with heart disease are the group most at risk
	People with asthma, children, and older adults are the groups most at risk
SO_2	People with asthma, children, and older adults are the groups most at risk

An API report may also contain, but does not require:

- The name and index value for other pollutants, particularly those with an index value greater than100,
- The index for sub-areas of the reporting area,
- Actual pollutant concentrations,
- Causes for unusual API values,
- Health effects and cautionary language,
- Statements that "blend" health effects and cautionary information for more than one pollutant, if there is more than one pollutant with an index value greater than 100.

The report of API must include the effect of air pollutants to sensitive group and normal people. Health advisory also needs to be given for the sensitive group and normal people

especially during air pollution episode such as during haze phenomenon in Southeast Asia. Example of API reporting in website and newspaper is shown in Table 8.3.

Table 8.3: Example of air pollution index report

Report as of:	2:00PM	**API:**	180	**Responsible pollutant:**	Ozone
Code:	Orange	**Category:**	Unhealthy		
Sensitive groups:	Active children and adults, and people with lung disease, such as asthma, should reduce prolonged or heavy outdoor exertion.				
Health effects:	Greater likelihood of respiratory symptoms and breathing difficulty in sensitive groups, possible respiratory effects in the general population.				
HEALTH ADVISORY:	Children and adults who are active outdoors, and people with lung disease, such as asthma should avoid moderate exertion outdoors, everyone else (especially children) should limit prolonged or heavy outdoor exertion				

For colour blind individuals, instead of presenting API information with just different colored circles on the ASMC haze map in the DOE website, each category is also represented by individual shapes. Figure 8.1 presents the suggested shapes.

Current ASMC Haze Map Presentation

Suggested ASMC Haze Map Presentation with Suggested Colour Code and Shape

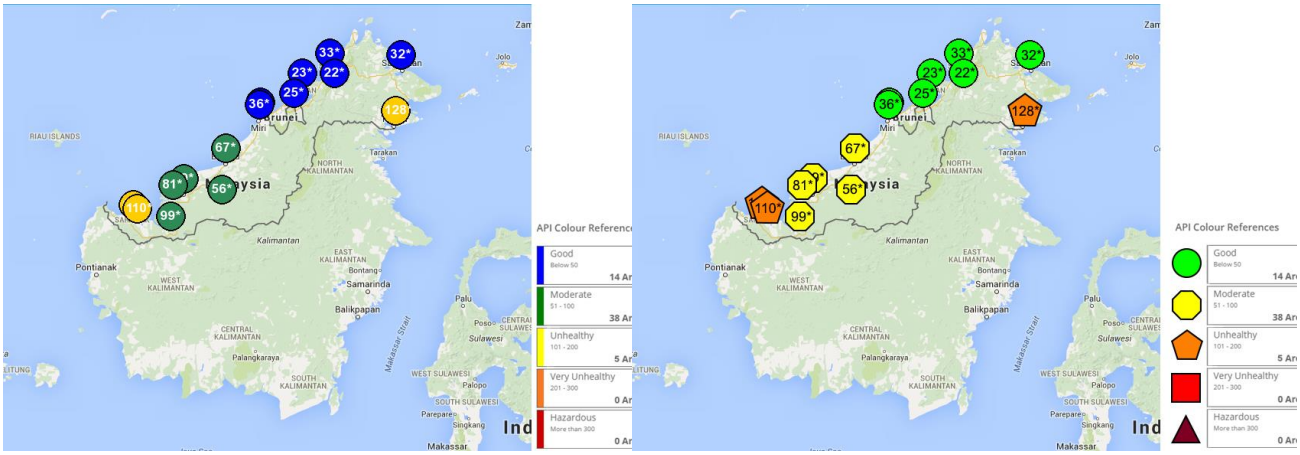

Figure 8.1 Suggested colour code and shape for each API category to be used for presenting ASMC haze map

9.0 New API and Haze Action Plan.

Haze is a phenomenon where visibility is reduced because of light scattering. Hazy condition can occur due to the high concentration of fine particles, dust, water vapour and photochemical smog. In Malaysia, hazy condition usually occur during the southwest monsoon due to high concentration of particulate matter released from peat soil combustion in Sumatra and Kalimantan, Indonesia[29]. The combustion from these areas usually can contribute to the smouldering type of burning which usually release more smoke into the atmosphere. The small particles in the atmosphere will scatter light, reducing visibility, creating the haze phenomenon. The haze phenomenon usually can be predicted by the increasing number of hotspots in Southeast Asian region.

Based on the current API calculation and API calculation using other methods described in this report (Section 2.0, Table 2.1), particulate matter (PM) is the main parameter that would require extra attention during haze episode. This is because, all of the methods which determine the API value by taking the highest sub-index value from different pollutants show that PM is the only pollutant which can reach above unhealthy level during haze episode and therefore the main

determinant of the API. Study by Azmi et al.[30] also shows that during haze episode in 1997 and 2005 the concentration of particulate matter was recorded significantly higher compared to other pollutants.

Malaysian Department of Environment (DOE) is suggested to take into account the concentration of $PM_{2.5}$ when determining the API, especially during haze episode. Study by Betha et al.[31] shows that during the haze episode in Southeast Asia in 2013, the concentration of fine aerosols (d< 0.1 µm) dominated the number of particles (Figure 9.1). Therefore, it is very important to focus on fine aerosols such as aerosols with diameter below than 2.5 µm ($PM_{2.5}$) compare to PM_{10}.

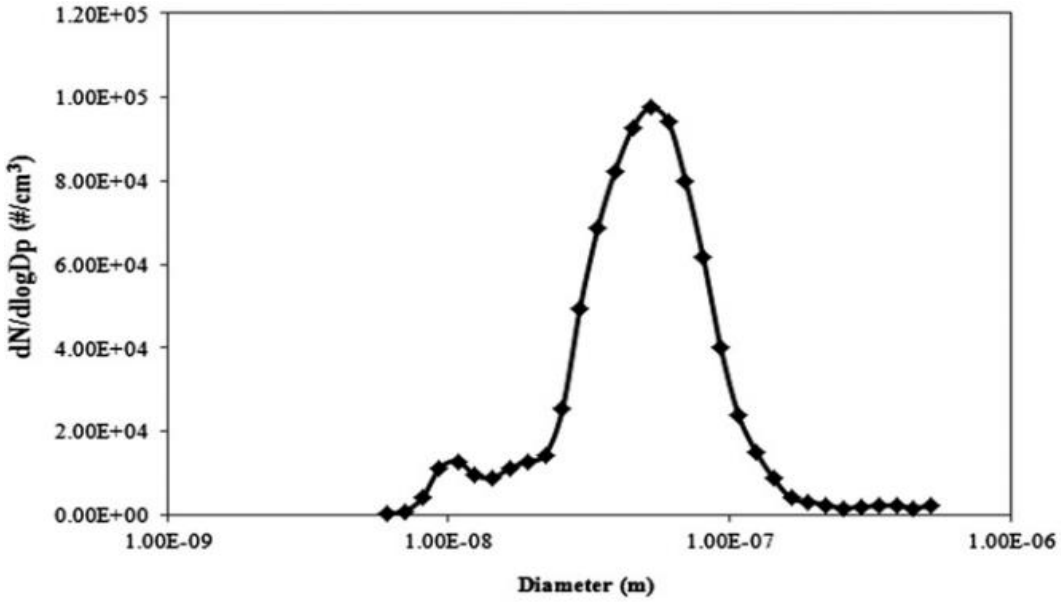

Figure 9.1: Number of particles based on size during haze episode in Singapore in 2013[30]

Several procedures need to be conducted when API value is above 100 (Unhealthy for Sensitive Group) during haze episode. The group that usually affected from haze episode is the group of people which have chronic lung and heart diseases. Other than that, children, elderly and pregnant woman also can be categorised as sensitive group. At this API level, information on precautionary procedures need to be distributed to all electronic media such as TV, radio, DOE's website, Twitter, Facebook etc. The information on how to reduce the inhalation of particles need be distributed with the information of haze. Specific mask (such as N95) which is suitable to reduce

the inhalation of fine and ultrafine particles need to be distributed especially to school children and people from the sensitive group. Other than API, the concentration of hourly $PM_{2.5}$ and its effect to human health needs to be mentioned in the API report starting from this level. The hourly concentration of $PM_{2.5}$ is good indicator to determine the current level of haze compare to 24-h averaging API value. Since our $PM_{2.5}$ standard in above the value of 25 $\mu g/m^3$ and 35 $\mu g/m^3$ as suggested by World Health Organisation (WHO) and USEPA and for $PM_{2.5}$ standard respectively, the information on the concentration of $PM_{2.5}$ is important for alert the public on the effect of fine particulate matter to human health.

When API is above 200 (unhealthy level), the government is suggested to instruct the public to be on full alert of the unhealthy level of air pollutants. All public and private agencies especially schools should be advised to reduce outdoor activities and remain indoor. This is because, at this level of API, even a healthy person is expected to be affected by the haze episode.

When API is more than 300, the government is suggested to give warning to the public on the unhealthy level of air pollutants. All outdoor activities need to be reduced or stop completely unless they are of dire necessary. The government is suggested to instruct Education Ministry to close all schools and stop all outdoor activities. People is to be advised to the needs to remain indoor unless necessary. Further detailed procedure can be obtained from the Malaysian National Haze Action Plan[32].

10.0 Summary

This study used the long term record of air quality data with a focus on 2005 to calculate the Air Pollution Index in Malaysia. In general, the API calculated using different methods of calculation show almost similar air quality condition especially during haze episode. Each method has its own advantages and weaknesses for API calculation. Based on its application in many countries in this region as well as its application by Malaysian Department of Environment currently, the formula used by United State Environmental Agency with modification of breakpoints has been suggested for calculation of API starting from 2017.

With the addition of $PM_{2.5}$, this parameter is expected to be the main parameter for API calculation. API based on $PM_{2.5}$ will increase the API value around 40% compared to API calculated using PM_{10}. Based on the new Malaysian Air Quality Standard, this study suggests that the breakpoints between moderate and unhealthy level to follow the concentration of $PM_{2.5}$ standard of 75 $\mu g/m^3$ (IT-1 2015), 50 $\mu g/m^3$ (IT-2 2018) and 35 $\mu g/m^3$ (IT-3 2020). The lower breakpoints of unhealthy suggested are 75.5 $\mu g/m^3$, 50.5 $\mu g/m^3$ and 35.5 $\mu g/m^3$, respectively. The breakpoints of 75.5 $\mu g/m^3$ can be used in 2017 when DOE start to measure $PM_{2.5}$ in their continuous stations. The API value using this breakpoint is expected to increase the API value more than 40% compare to API calculate using PM_{10}. Nevertheless the API value using this breakpoint 75.5 $\mu g/m^3$ will be far lower compare to air quality index calculate by our neighbour country such as Singapore. Therefore, this study suggests that IT-2 (2018) can be used in 2017 for API calculation when Malaysia starts to implement new calculation using $PM_{2.5}$ in 2017.The breakpoints for IT-3 2020 can be revised based on the $PM_{2.5}$ data from 2017 until 2020. At the same time, the standardisation of air quality index breakpoints for ASEAN countries are suggested especially during haze episode in Southeast Asia.

The new presentation of API will improve the understanding of API calculation through distribution of information in the website and in a booklet to the public. During haze episode the API values will be presented with additional information such as visibility, hourly and 24-h $PM_{2.5}$ concentration. This will alert the public on the situation of current condition in addition to the value of API based on 24-h average of $PM_{2.5}$.

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Appendixes

Appendix 1: The API Calculation Excel Spread Sheet

Appendix 2: API Booklet

Appendix 3: New Malaysia Ambient Air Quality Standard.

Appendix 4: A Guide to Air Pollutant Index in Malaysia (API) 1997

Glossary

Air Pollutant Index (API): A value to report status of air quality and its relation to human health. It uses colors and numbers to inform how good or unhealthy the air quality at specific time is and how it may affect public health.

Breakpoint: A concentration of air pollutant to differentciate the different categories of health impact in Air Pollutant Index. The lower breakpoint is the the lower concentration of air pollutant in the specific category and the upper breakpoint is the highest concentration of that similar category.

Sensitive groups: Group of people who are easily affected to air pollution. Elderly and children are belong to this group. People with heart disease or lung disease such as asthma, children and teens, people who are active outdoors, and older adults.

Haze episode: A condition where the visibility reduce due to light scattering of small particles in the atmosphere.

Hazardous air: Status of air quality that affected the whole population due to high concentration of air pollutants. This is usually an emergency conditions for health perspective. The entire population is more likely to be affected.

APPENDIX 1

Excel spreaed sheet for calculating Malaysia New Air Pollutant Index (API)

USER'S INPUT																								
Type of Pollutants	Data																							
	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
O3 (8 hr)	0	0	0	0	0	0	0	0																
O3 (1 hr)	0																							
PM 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PM 2.5 (2018)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PM 2.5 (2020)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CO	0	0	0	0	0	0	0	0																
SO2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NO2	0																							

Malaysia DOE API (US-EPA) Calculator				
Type of Pollutants	Running mean	Units	Mean value	Sub Index
O3	8 hr	ppm	0	0
	1 hr	ppm	0	0
PM10	24 hr	µg/m3	0	0
PM2.5 (2018)	24 hr	µg/m3	0	0
PM2.5 (2020)	24 hr	µg/m3	0	0
CO	8 hr	ppm	0	0
SO2	24 hr	ppm	0	0
NO2	1 hr	ppm	0	0
		API and Colour Code		0

The API calculation Excel spread sheet comprises of two parts, i) user's input and ii) API calculation based on user's input. To get started, user simply paste in the required pollutants data. The unit for the pollutants should be:

i. part per million (ppm) for O_3, CO, SO_2 and NO_2
ii. micro gram per meter cubic ($\mu g/m^3$) for PM_{10} and $PM_{2.5}$

Figure 1 shows an example of the calculation of API using dummy data. In this calculation, the API sub index of NO_2 is the highest and was used to decide the API, therefore the sub index box was sketched. The API calculated for this hour is 209, which is at the "very unhealthy", hence, the "API and Colour Code" box is painted red.

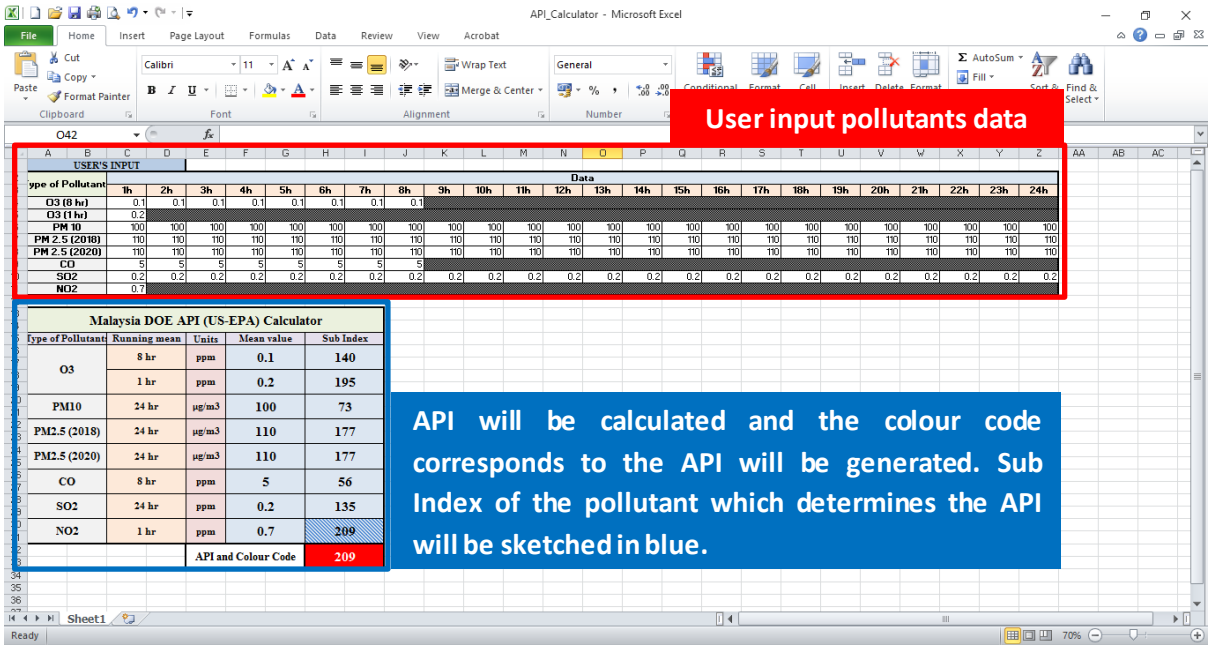


Figure 1. Screen shot of sample calculation of API using the Excel spread sheet using dummy data.

Should the user would want to exclude some pollutant criteria in the calculation, the user should either leave the correspond row empty or fill it with zeros. The sub index for that criteria will be given zero by the Excel spread sheet (Figure 2)

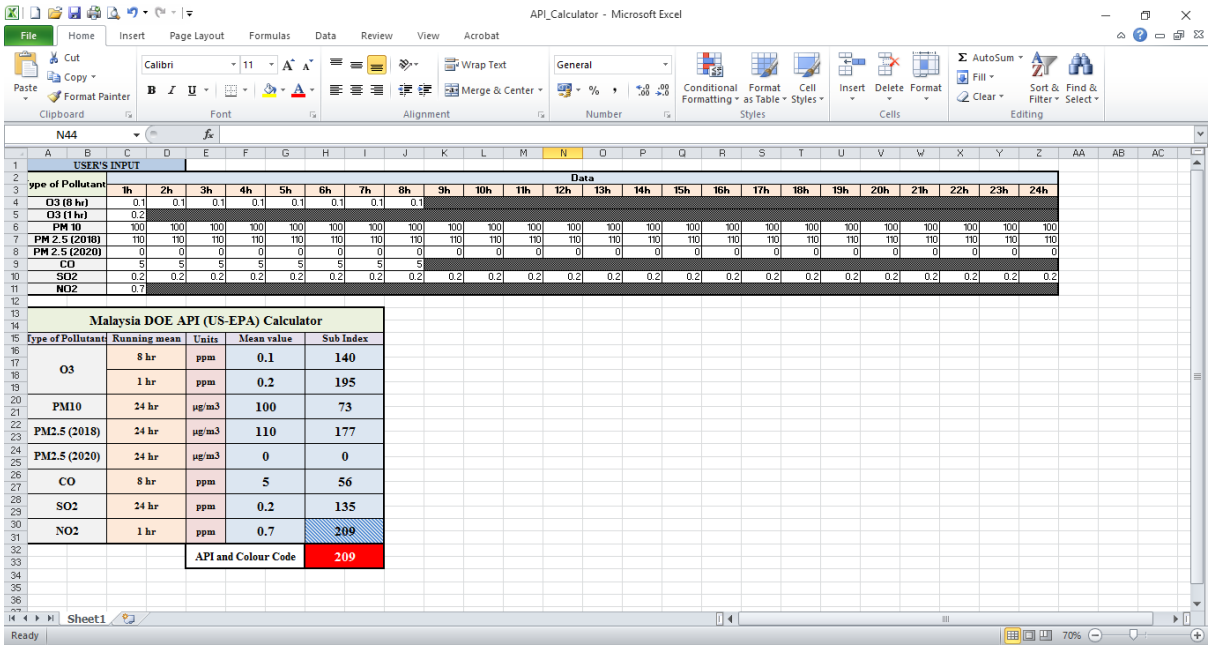
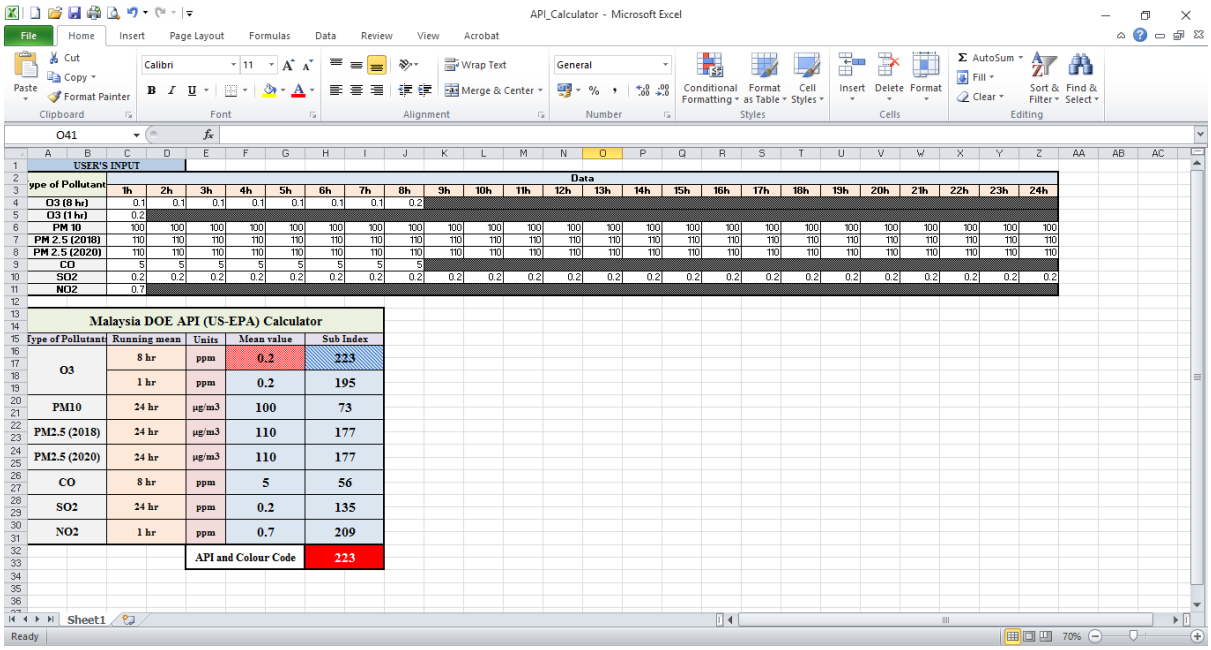


Figure 2. Example calculation where the criteria for $PM_{2.5}$ with year 2020 target was to leave out of the calculation.

The determination of 8 hour O_3 sub index is a bit tricky, where should the most recent one hour concentration higher than a designated amount, 1 hour O_3 will be used to determine the sub index. To alert the user of such calculation in this situation, the "Mean value" box will be sketch red (Figure 3).

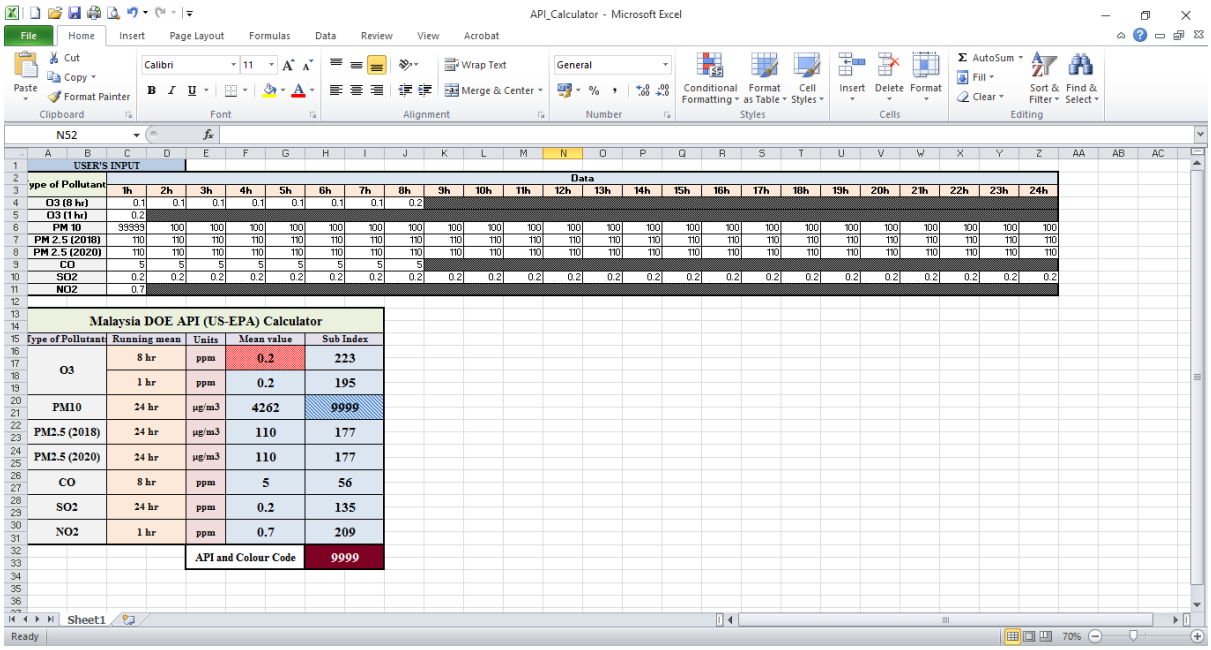


USER'S INPUT																								
Type of Pollutant	Data																							
	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
O3 (8 hr)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2																
O3 (1 hr)	0.2																							
PM 10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PM 2.5 (2018)	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
PM 2.5 (2020)	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
CO	5	5	5	5	5	5	5	5																
SO2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NO2	0.7																							

Malaysia DOE API (US-EPA) Calculator				
Type of Pollutant	Running mean	Units	Mean value	Sub Index
O3	8 hr	ppm	0.2	223
	1 hr	ppm	0.2	195
PM10	24 hr	µg/m3	100	73
PM2.5 (2018)	24 hr	µg/m3	110	177
PM2.5 (2020)	24 hr	µg/m3	110	177
CO	8 hr	ppm	5	56
SO2	24 hr	ppm	0.2	135
NO2	1 hr	ppm	0.7	209
		API and Colour Code		223

Figure 3. The "Mean value" box of O_3 was sketch red because 1 hour O_3 was used to determine the sub index instead of usual 8 hourly mean O_3.

Should the user's data mean value is over the limit set to define the API, a value of 9999 will be given (Figure 4)



USER'S INPUT																								
Type of Pollutant	Data																							
	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h	24h
O3 (8 hr)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2																
O3 (1 hr)	0.2																							
PM 10	99999	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PM 2.5 (2018)	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
PM 2.5 (2020)	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
CO	5	5	5	5	5	5	5	5																
SO2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NO2	0.7																							

Malaysia DOE API (US-EPA) Calculator				
Type of Pollutant	Running mean	Units	Mean value	Sub Index
O3	8 hr	ppm	0.2	223
	1 hr	ppm	0.2	195
PM10	24 hr	µg/m3	4262	9999
PM2.5 (2018)	24 hr	µg/m3	110	177
PM2.5 (2020)	24 hr	µg/m3	110	177
CO	8 hr	ppm	5	56
SO2	24 hr	ppm	0.2	135
NO2	1 hr	ppm	0.7	209
		API and Colour Code		9999

Figure 4. A value of 9999 is given to the calculation because one of the criteria exceed the API determination limit.

APPENDIX 2

A Guide to Malaysian New Air Pollutant Index (API)

Malaysian Department of Environment
Ministry of Natural Resources and Environment

1.0 Introduction

Air pollution is a major concern of our society these days. Air pollutants can be generated from various natural and man-made sources. Emission from sea surface, forested areas and soil dust are some of the natural sources of air pollutants. These sources usually contribute to the background level of air pollutants in ambient air. Other than natural sources, various man-made activities such as emission from motor vehicles, industrial activities and biomass burning may also contribute to the high level of air pollutants in ambient air. Since the beginning of industrial era in 19^{th} century, man-made sources of air pollutants seem to dominate the level of air pollutants in ambient air, greatly deteriorating the air quality. As polluted air can cause various health complications to humans, the ability to disseminate information on the severity of air pollution at a particular time and region to the public and policy makers is therefore important.

Air pollutants index (API) was designed to be a simple numerical scale mechanism to correlate air pollutants concentration to human health. The API scale represents a broad range of air quality ranging from pristine air to “hazardous air” and focuses on the health effects a person may experiences within a few hours or days after being exposed to the polluted air. The calculation of API is based on five major air pollutants namely particulate matter with aerodynamic diameter below than 10 micrometer (PM_{10}), particulate matter with aerodynamic diameter below than 2.5 micrometer ($PM_{2.5}$), ground level ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). Calculation of sub-index of each pollutant is based on each sub-index formula. The highest sub-index will become the API value for that particular time (Figure 1)

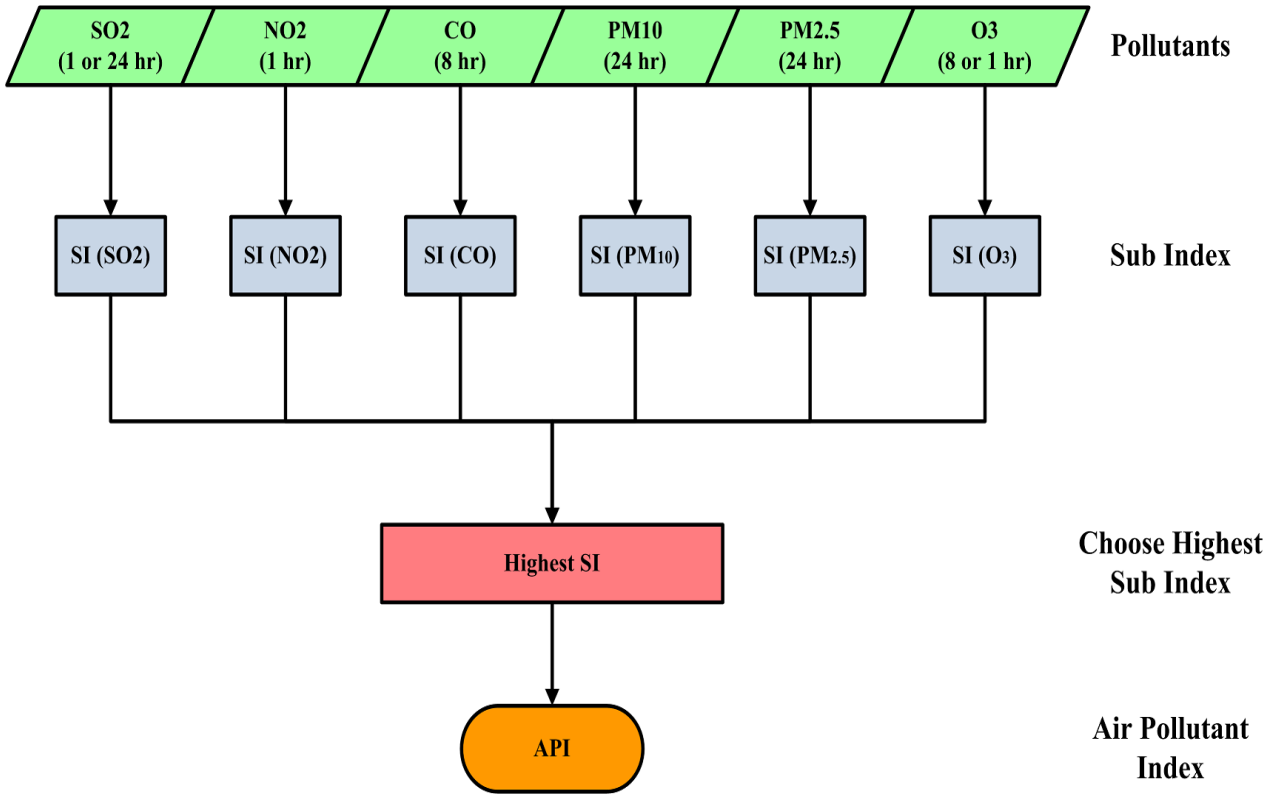


Figure 1: The diagram of calculation of Air Pollutants Index (API) in Malaysia

2.0 How API is being calculated?

The calculation of API in Malaysia is based on the United States Environmental Protection Agency's Air Quality Index formula (Eq. 1), using the air pollutant concentration data observed by the continuous air quality monitoring (CAQM) stations of the Malaysian Department of Environment. The concentrations of the six air pollutants used for API sub-index calculations are based on the measurement of the pollutant concentrations in specific averaging time. The concentration breakpoints of the air pollutants used to determine the category of the SI (Sub Index) are based on their impact to human health (Table 1). These breakpoints also consider the background of the concentrations of the pollutants in our tropical conditions, especially for particulate matter with aerodynamic size below than 2.5 micrometre ($PM_{2.5}$). Table 1 shows the pollutant-specific sub-indices and cautionary statements for guidance on the Air Pollutant Index (API). Table 2 shows the summary of breakpoint to be used for each pollutant when calculating the API. The breakpoints of each pollutant with their averaging time are shown in Figure 3 to 8.

The generalized equation of API calculation

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{Hi} - BP_{Lo}} (X_P - BP_{Lo}) + I_{Lo} \qquad \text{Eq. 1}$$

Where I_p = the index for pollutant p

X_p = the rounded concentration of pollutant p

BP_{Hi} = the breakpoint that is greater than or equal to X_p

BP_{Lo} = the breakpoint that is less than or equal to X_p

I_{Hi} = the API value corresponding to BP_{Hi}

I_{Lo} = the API value corresponding to BP_{Lo}

Table 1Pollutant-SpecificCautionary Statements for Guidance on the Air Pollutant Index (API)

API Categories (Index Values)	Ozone (ppm)		Particulate Matter(µg/m^3)		Carbon Monoxide (ppm) [8-h]	Sulphur Dioxide (ppb) [1-h]	Nitrogen Dioxide (ppb) [1-h]
	[8-h]	[1-h]	$PM_{2.5}$ [24-h]	PM_{10} [24-h]			
Good (Upto50)	None	-	None	None	None	None	None
Moderate (51-100)	Unusually sensitive people should consider reducing prolonged or heavy outdoorexertion.	-	Unusually sensitive people should consider reducing prolonged or heavy exertion.		None	None	Unusually sensitive individuals should consider limiting prolonged exertion especially near busy roads.
Unhealthy for Sensitive Groups (101-150)	People with lung disease, such as asthma, children, older adults, and outdoor workers should reduce prolonged or heavy outdoor exertion.		People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.		People with heart disease, such as angina, should limit heavy exertion and avoid sources of CO, such as heavy traffic.	People with asthma should consider limiting outdoor exertion.	People with asthma, children and older adults should limit prolonged exertion especially near busy roads.

Continuation of Table 1

Unhealthy (151-200)	People with lung disease, such as asthma, children, older adults, and outdoor workers should avoid prolonged or heavy outdoor exertion; everyone else should reduce prolonged or heavy outdoor exertion.	People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion.	People with heart disease, such as angina, should limit moderate exertion and avoid sources of CO, such as heavy traffic.	Children, people with asthma, or other lung diseases, should limit outdoor exertion	People with asthma, children and older adults should avoid prolonged exertion near roadways; everyone else should limit prolonged exertion especially near busy roads.
Very Unhealthy (201-300)	People with lung disease, such as asthma, children, older adults, and outdoor workers should avoid all outdoor exertion; everyone else should reduce outdoor exertion.	People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.	People with heart disease, such as angina, should avoid exertion and sources of CO, such as heavy traffic.	Children, people with asthma, or other lung diseases should avoid outdoor exertion; everyone else should reduce outdoor exertion.	People with asthma, children and older adults should avoid all outdoor exertion; everyone else should avoid prolonged exertion especially near busy roads.
Hazardous (301-500)	Everyone should avoid all outdoor exertion.	Everyone should avoid all physical activity outdoors; people with heart or lung disease, older adults, and children should remain indoors and keep activity level slow.	People with heart disease, such as angina, should avoid exertion and sources of CO, such as heavy traffic; everyone else should limit heavy exertion	Children, people with asthma, or other lung diseases, should remain indoors; everyone else should avoid outdoor exertion.	People with asthma, children and older adults should remain indoors; everyone else should avoid all outdoor exertion.

Source: USEPA (2013)

Table 2:**Breakpoints values for the API calculation based on USEPA health impact study and Malaysian Air Quality Standard**

Category	API	Parameter Breakpoint						
Parameter		O_3 (ppm)	O_3 (ppm)	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)
Averaging Time		8-h	1-h	24-h	24-h	8-h	1-h	1-h
Good	0-50	0.000-0.059	-	0-54	0.0-12.0	0.0-4.4	0.000-0.035	0.000-0.053
Moderate	51-100	0.060-0.075	-	55-154	12.1-75.4[5] 12.1-50.4[6] 12.1-35.4[7]	4.5-9.4	0.036-0.075	0.054-0.100
Unhealthy for Sensitive Groups	101-150	0.076-0.095	0.125-0.164	155-254	75.5-150.4[5*] 50.5-55.4[6] 35.5-55.4[7]	9.5-12.4	0.076-0.185	0.101-0.360
Unhealthy	151-200	0.096-0.115	0.165-0.204	255-354	55.5-150.4	12.5-15.4	(0.186-0.304)[4]	0.361-0.649
Very unhealthy	201-300	0.116-0.374	0.205-0.404	355-424	150.5-250.4	15.5-30.4	(0.305-0.604)[4]	0.650-1.249
Hazardous	301-400	([2])	0.405-0.504	425-504	250.5-350.4	30.5-0.4	(0.605-0.804)[4]	1.250-1.649
Hazardous	401-500	([2])	0.505-0.604	505-604	350.5-500.4	40.5-0.4	(0.805-1.004)[4]	1.650-2.049

[1]Areas are required to report the API based on 8-hO_3values. However, there are areas where an API based on 1-hO_3 values would be more protective. In these cases the index for both the 8-h and the 1-hO_3values may be calculated and the maximum API reported.
[2]8-h O_3 values do not define higher AQI values (≥ 301). AQI values of 301 or higher are calculated with 1- h O_3 concentrations.
[3]If a different SHL for $PM_{2.5}$ is promulgated, these numbers will change accordingly.
[4]1-h SO_2 values do not define higher AQI values (≥ 200). AQI values of 200 or greater are calculated with 24-h SO_2 concentrations.
[5]Based on Malaysian Air Quality Standard until 2015
[5*]Based on Malaysian Air Quality Standard until 2015 for API 101-200
[6]Based on Malaysian Air Quality Standard until 2018
[7]Based on Malaysian Air Quality Standard after 2020

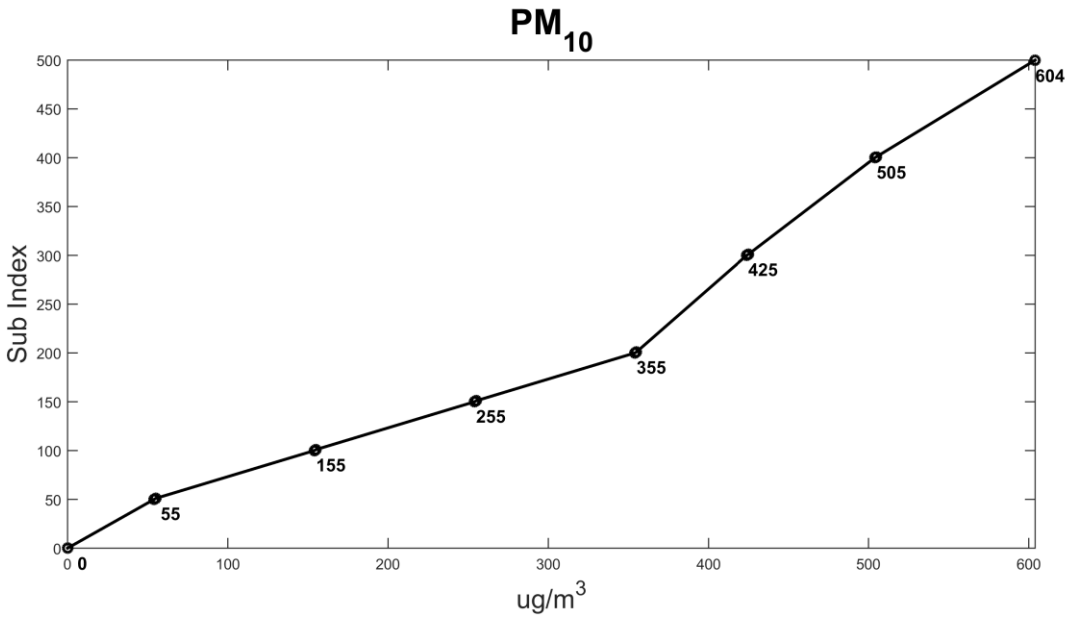


Figure 3: Breakpoints for PM_{10} for 24 hour averaging time

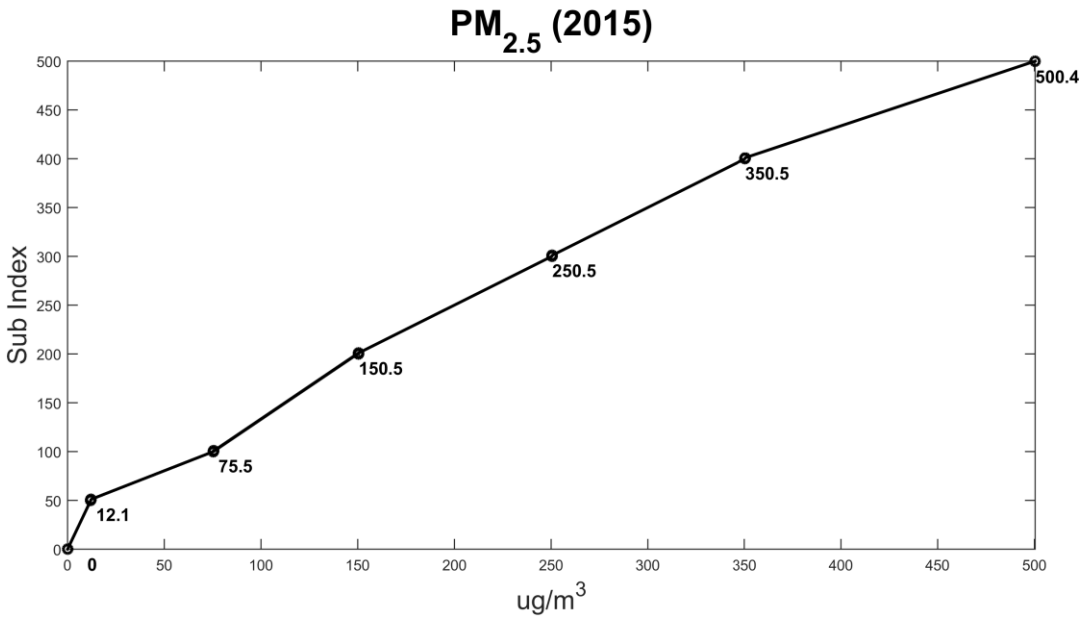


Figure 4a: Breakpoints for $PM_{2.5}$ for 24 hour averaging time (IT-1 2015)

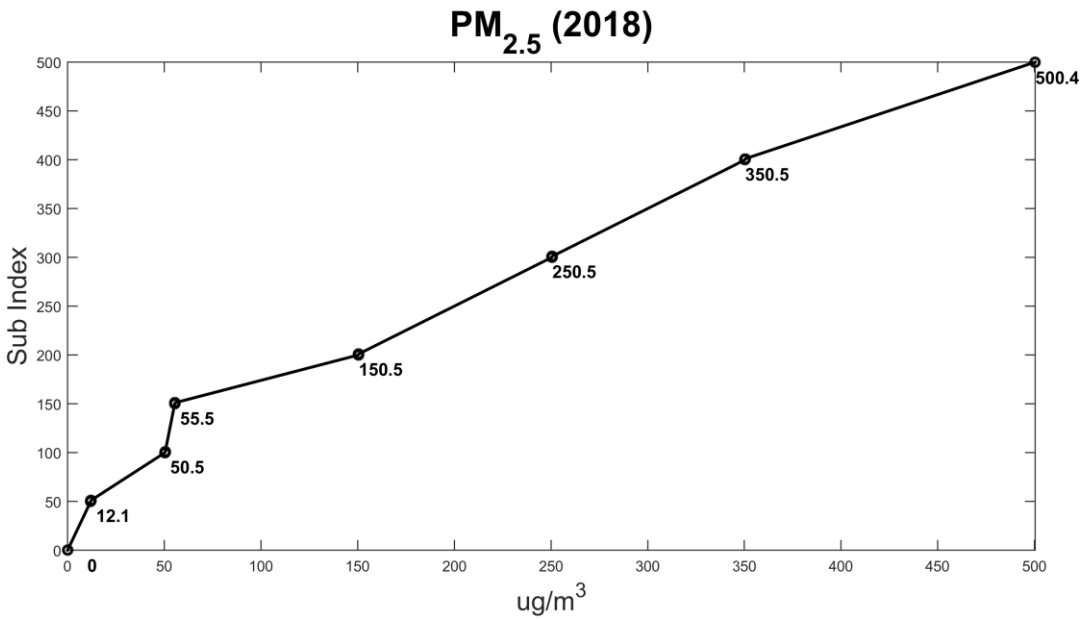


Figure 4b: Breakpoints for $PM_{2.5}$ for 24 hour averaging time (IT-2 2018)

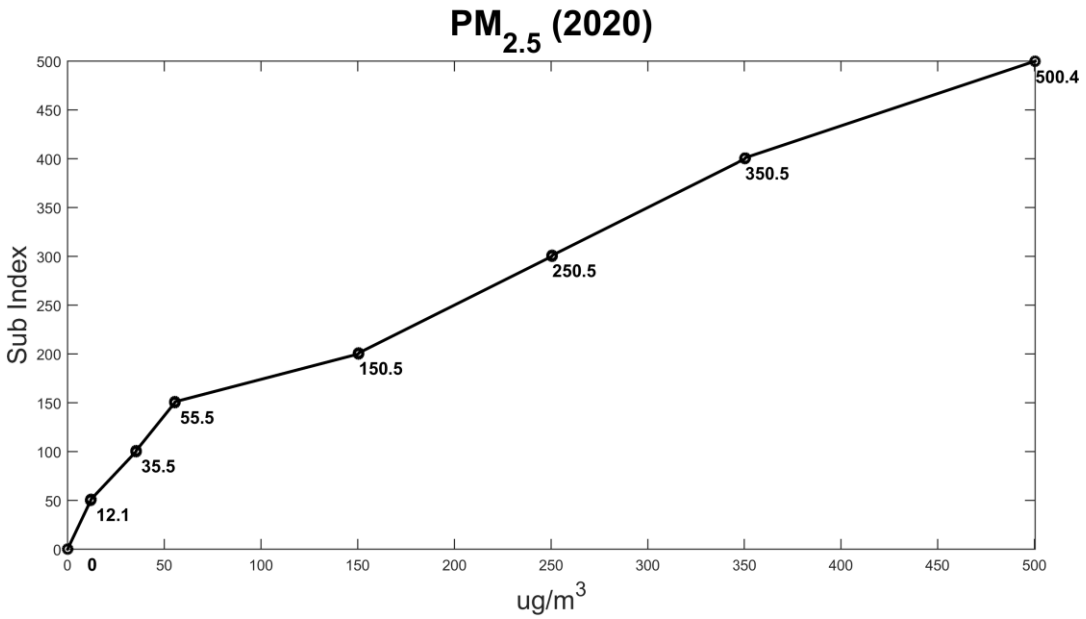


Figure 4c: Breakpoints for $PM_{2.5}$ for 24 hour averaging time (IT-3 2020)

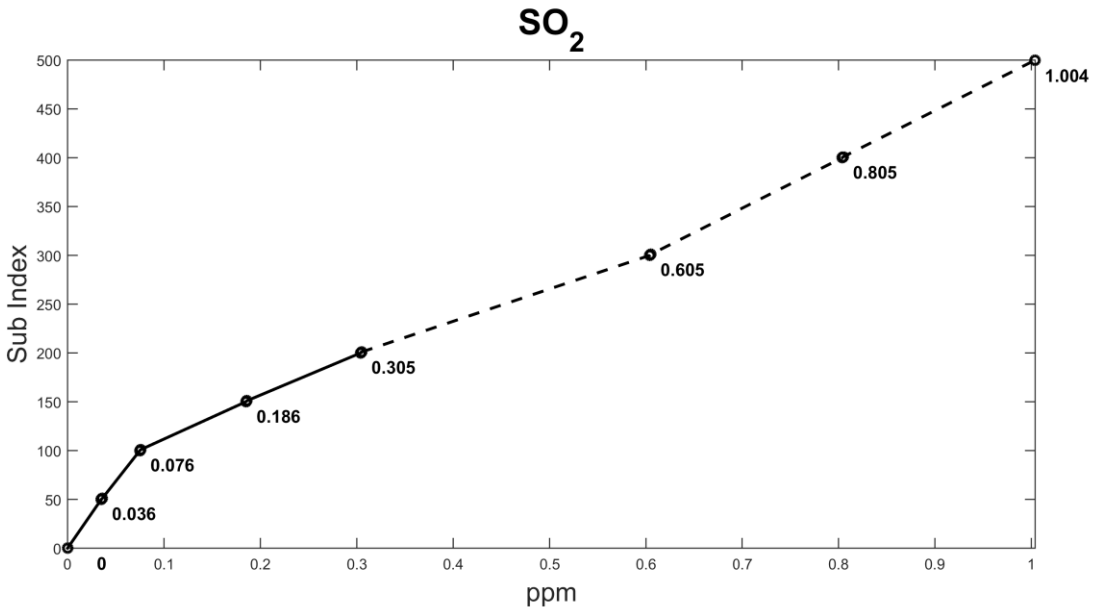


Figure 5: Breakpoints for ground-level ozone for 1 hour averaging time. Dashed line show that the sub-index are to be calculated using different averaging time (24 h).

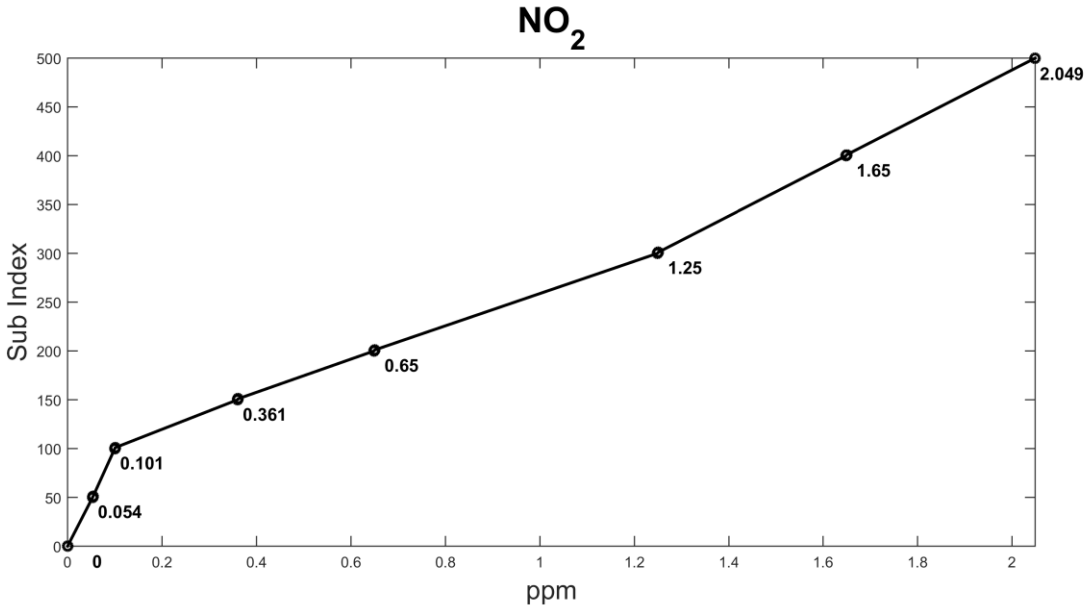


Figure 6: Breakpoints for ground-level NO_2 for 1 hour averaging time

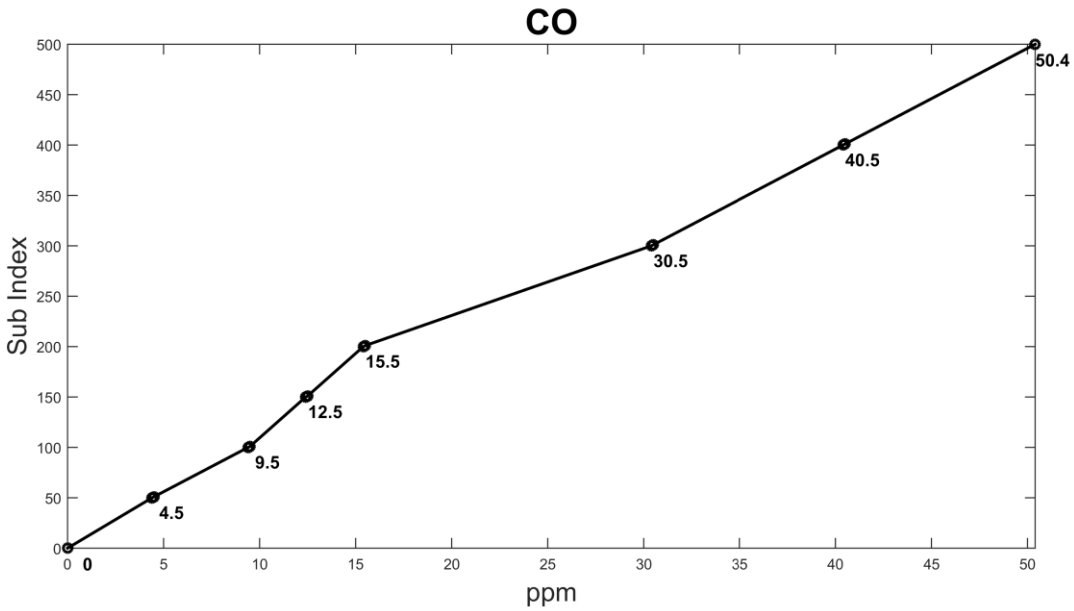


Figure 7: Breakpoints for CO for 8 hour averaging time (IT-3 2020)

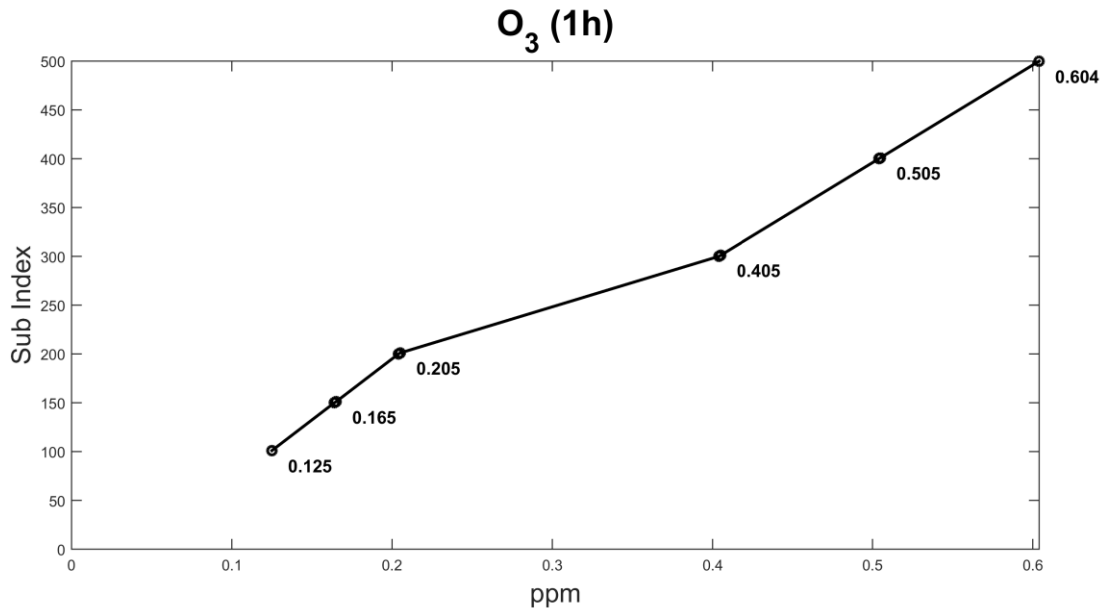


Figure 8a: Breakpoints for ground-level ozone for 1 hour averaging time

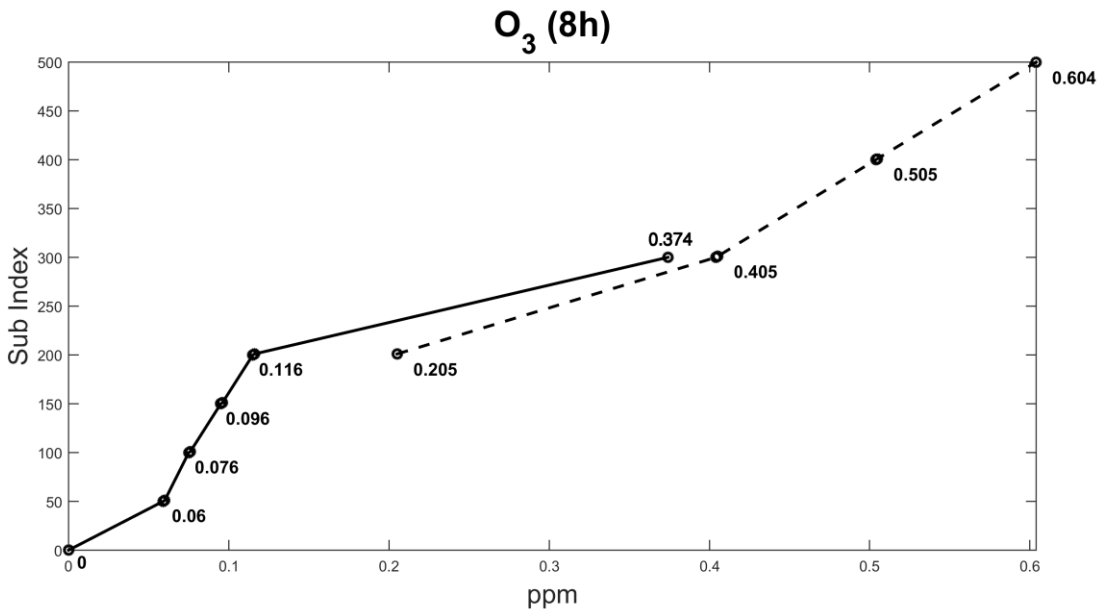


Figure 8b: Breakpoints for ground-level ozone for 8 hour averaging time. Dashed line shows that the sub-index are to be calculated using different averaging time (1 h averaging time).

3.0 Formula of Calculation

The formula for API calculation to suit with the new Malaysian Air Quality Standard are given in Table 3.1 to Table 3.6

Table 3.1 Summary table for PM_{10} API index calculation

API range	Breakpoint of concentration	Equation for API
X =PM_{10} (24 h average, unit: µg/m³)		
0-50	0 < X < 54	$API = \left(\frac{50-0}{54-0}\right) \times (X-0) + 0$
51-100	55 ≤ X ≤ 154	$API = \left(\frac{100-51}{154-55}\right) \times (X-55) + 51$
101-150	155 ≤ X ≤ 254	$API = \left(\frac{150-101}{254-155}\right) \times (X-155) + 101$
151-200	255 ≤ X ≤ 354	$API = \left(\frac{200-151}{354-255}\right) \times (X-255) + 151$
201-300	355 ≤ X ≤ 424	$API = \left(\frac{300-201}{424-355}\right) \times (X-355) + 201$
301-400	425 ≤ X ≤ 504	$API = \left(\frac{400-301}{504-425}\right) \times (X-425) + 301$
401-500	505 ≤ X ≤ 604	$API = \left(\frac{500-401}{604-505}\right) \times (X-505) + 401$

Table 3.2a Summary table for $PM_{2.5}$ API index calculation

API	Breakpoint of concentration	Equation for API
X = $PM_{2.5}$ (24 h average, unit: µg/m³)		
0-50	0 < X < 12.0	$API = \left(\frac{50-0}{12.0-0}\right) \times (X-0) + 0$
51-100	12.1 ≤ X ≤ 75.4	$API = \left(\frac{100-51}{75.4-12.1}\right) \times (X-12.1) + 51$
101-200	75.5 ≤ X ≤ 150.4	$API = \left(\frac{200-101}{150.4-75.5}\right) \times (X-75.5) + 101$
201-300	150.5 ≤ X ≤ 250.4	$API = \left(\frac{300-201}{250.4-150.5}\right) \times (X-150.5) + 201$
301-400	250.5 ≤ X ≤ 350.4	$API = \left(\frac{400-301}{350.4-250.5}\right) \times (X-250.5) + 301$
401-500	350.5 ≤ X ≤ 500.4	$API = \left(\frac{500-401}{500.4-350.5}\right) \times (X-350.5) + 401$

Note: This calculation is based on Malaysian Air Quality Standard 2015

Table 3.2b Summary table for $PM_{2.5}$ API index calculation

API	Breakpoint of concentration	Equation for API
X = $PM_{2.5}$ (24 h average, unit: µg/m³)		
0-50	0 < X < 12.0	$API = \left(\frac{50-0}{12.0-0}\right) \times (X-0) + 0$
51-100	12.1 ≤ X ≤ 50.4	$API = \left(\frac{100-51}{50.4-12.1}\right) \times (X-12.1) + 51$
101-150	50.5 ≤ X ≤ 55.4	$API = \left(\frac{150-101}{55.4-50.5}\right) \times (X-50.5) + 101$
151-200	55.5 ≤ X ≤ 150.4	$API = \left(\frac{200-151}{150.4-55.5}\right) \times (X-55.5) + 151$
201-300	150.5 ≤ X ≤ 250.4	$API = \left(\frac{300-201}{250.4-150.5}\right) \times (X-150.5) + 201$
301-400	250.5 ≤ X ≤ 350.4	$API = \left(\frac{400-301}{350.4-250.5}\right) \times (X-250.5) + 301$
401-500	350.5 ≤ X ≤ 500.4	$API = \left(\frac{500-401}{500.4-350.5}\right) \times (X-350.5) + 401$

Note: This calculation is based on Malaysian Air Quality Standard 2018

Table 3.2c Summary table for $PM_{2.5}$ API index calculation

API	Breakpoint of concentration	Equation for API
X = $PM_{2.5}$ (24 h average, unit: µg/m³)		
0-50	0 < X < 12.0	$API = \left(\frac{50-0}{12.0-0}\right) \times (X-0) + 0$
51-100	12.1 ≤ X ≤ 35.4	$API = \left(\frac{100-51}{35.4-12.1}\right) \times (X-12.1) + 51$
101-150	35.5 ≤ X ≤ 55.4	$API = \left(\frac{150-101}{55.4-35.5}\right) \times (X-35.5) + 101$
151-200	55.5 ≤ X ≤ 150.4	$API = \left(\frac{200-151}{150.4-55.5}\right) \times (X-55.5) + 151$
201-300	150.5 ≤ X ≤ 250.4	$API = \left(\frac{300-201}{250.4-150.5}\right) \times (X-150.5) + 201$
301-400	250.5 ≤ X ≤ 350.4	$API = \left(\frac{400-301}{350.4-250.5}\right) \times (X-250.5) + 301$
401-500	350.5 ≤ X ≤ 500.4	$API = \left(\frac{500-401}{500.4-350.5}\right) \times (X-350.5) + 401$

Note: This calculation is based on Malaysian Air Quality Standard 2020

Table 3.3 Summary table for SO_2 API index calculation

API	Breakpoint of concentration	Equation for API
X = SO_2 (1 h average, unit: ppm)		
0-50	0.000 < X < 0.035	$API = \left(\frac{50-0}{0.035-0}\right) \times (X-0) + 0$
51-100	0.036 ≤ X ≤ 0.075	$API = \left(\frac{100-51}{0.075-0.036}\right) \times (X-0.036) + 51$
101-150	0.076 ≤ X ≤ 0.185	$API = \left(\frac{150-101}{0.185-0.076}\right) \times (X-0.076) + 101$
151-200	0.186⩽X⩽ 0.304	$API = \left(\frac{200-151}{0.304-0.186}\right) \times (X-0.186) + 151$ (a) 24-h SO_2, the conc. is lower than 0.186, then we use 1-h SO_2 (b) Or If you have a daily max 1-h SO_2 concentration below 0.305 ppm, then use 1-h breakpoints in Table XX to calculate the AQI value
201-300	0.305 ≤ X ≤ 0.604	$API = \left(\frac{300-201}{0.604-0.305}\right) \times (X-0.305) + 201$ (a) If you have a 24-h average SO_2 concentration greater than or equal to 0.305 ppm, then use 24-h the breakpoints in Table XX to calculate the AQI value. (b) On rare occasions, you could have a day where the daily max 1-h concentration is at or above 0.305 ppm but when you try to use the 24-h average to calculate the AQI value, you find that the 24-h concentration is not above 0.305 ppm. If this happens, use 200 for the lower and upper AQI breakpoints (ILo and IHi) in Eq. 1 to calculate the AQI value based on the daily max 1-h value.
301-400	0.605 ≤ X ≤ 0.804	$API = \left(\frac{400-301}{0.804-0.605}\right) \times (X-0.605) + 301$
401-500	0.805 ≤ X ≤ 1.004	$API = \left(\frac{500-401}{1.004-0.805}\right) \times (X-0.805) + 401$

Table 3.4 Summary table for CO API index calculation

API	Breakpoint of concentration	Equation for API
X = CO (8 h average, unit: ppm)		
0-50	0 < X < 4.4	$API = \left(\frac{50-0}{4.4-0}\right) \times (X-0) + 0$
51-100	4.5 ≤ X ≤ 9.4	$API = \left(\frac{100-51}{9.4-4.5}\right) \times (X-4.5) + 51$
101-150	9.5 ≤ X ≤ 12.4	$API = \left(\frac{150-101}{12.4-9.5}\right) \times (X-9.5) + 101$
151-200	12.5 ≤ X ≤ 15.4	$API = \left(\frac{200-151}{15.4-12.5}\right) \times (X-12.5) + 151$
201-300	15.5 ≤ X ≤ 30.4	$API = \left(\frac{300-201}{30.4-15.5}\right) \times (X-15.5) + 201$
301-400	30.5 ≤ X ≤ 40.4	$API = \left(\frac{400-301}{40.4-30.5}\right) \times (X-30.5) + 301$
401-500	40.5 ≤ X ≤ 50.4	$API = \left(\frac{500-401}{50.4-40.5}\right) \times (X-40.5) + 401$

Table 3.5 Summary table for NO_2 API index calculation

API	Breakpoint of concentration	Equation for API
X = NO_2 (1 h average, unit: ppm)		
0-50	0.000 < X < 0.053	$API = \left(\frac{50-0}{0.053-0.000}\right) \times (X-0.000) + 0$
51-100	0.054 ≤ X ≤ 0.100	$API = \left(\frac{100-51}{0.100-0.054}\right) \times (X-0.054) + 51$
101-150	0.101 ≤ X ≤ 0.360	$API = \left(\frac{150-101}{0.360-0.101}\right) \times (X-0.101) + 101$
151-200	0.361 ≤ X ≤ 0.649	$API = \left(\frac{200-151}{0.649-0.361}\right) \times (X-0.361) + 101$
201-300	0.650 ≤ X ≤ 1.249	$API = \left(\frac{300-201}{1.249-0.650}\right) \times (X-0.650) + 201$
301-400	1.250 ≤ X ≤ 1.649	$API = \left(\frac{400-301}{1.649-1.250}\right) \times (X-1.250) + 301$
401-500	1.650 ≤ X ≤ 2.049	$API = \left(\frac{500-401}{2.049-1.650}\right) \times (X-1.650) + 401$

Table 3.6 Summary table for Ozone API index calculation

API range	Breakpoint of concentration	$Equation\ for\ API$
X =O_3 (8 h average, unit: ppm)		
0-50	0.000 < X < 0.059	$API = \left(\frac{50-0}{0.059-0.000}\right) \times (X - 0.000) + 0$
51-100	0.060 ≤ X ≤ 0.075	$API = \left(\frac{100-51}{0.075-0.060}\right) \times (X - 0.060) + 51$
101-150	0.076 ≤ X ≤ 0.095	$API = \left(\frac{150-101}{0.095-0.076}\right) \times (X - 0.076) + 101$
151-200	0.096 ≤ X ≤ 0.115	$API = \left(\frac{200-151}{0.115-0.096}\right) \times (X - 0.096) + 151$
201-300	0.116 ≤ X ≤ 0.374	$API = \left(\frac{300-201}{0.374-0.116}\right) \times (X - 0.116) + 201$
0.405 ≤ X ≤ 0.604		For the API for 8-hr O_3 conc., 0.116 [8-hr] - 0.404 [1-h] falls in API 201-300. In the same time, under the category API >301 for 8-hr O_3, 1-h conc. of O_3 is considered instead for the API, i.e. 0.405 [1-h] - 0.604 [1-h].
X =O_3 (1 h average, unit: ppm)		
101-150	0.125 ≤ X ≤ 0.164	$API = \left(\frac{150-101}{0.164-0.125}\right) \times (X - 0.125) + 101$
151-200	0.165 ≤ X ≤ 0.204	$API = \left(\frac{200-151}{0.204-0.165}\right) \times (X - 0.165) + 151$
201-300	0.205 ≤ X ≤ 0.404	$API = \left(\frac{300-201}{0.404-0.205}\right) \times (X - 0.205) + 201$
301-400	0.405 ≤ X ≤ 0.504	$API = \left(\frac{400-301}{0.504-0.405}\right) \times (X - 0.405) + 301$
401-500	0.505 ≤ X ≤ 0.604	$API = \left(\frac{500-401}{0.604-0.505}\right) \times (X - 0.505) + 401$

4.0 Example of Calculation

API can be calculated using Eq. 1 and the breakpoints in Table 1.

Example 1

If the concentrations of $PM_{2.5}$ for 24 hours average are 30 μgm^{-3} and 60 μgm^{-3}, the calculation of $PM_{2.5}$ sub-index based on Malaysian Air Quality Standard interim 3 (IT-3) period is as follows:

$PM_{2.5}$ = 30 μgm^{-3}

API for $PM_{2.5} = \left(\frac{100-51}{35.4-12.1}\right) \times (X - 12.1) + 51$=2.1030*(30-12.1) + 51 = 89

$PM_{2.5}$ = 60 μgm^{-3}

API for $PM_{2.5}$ = $\left(\frac{200-151}{150.4-55.5}\right) \times (X - 55.5) + 151$ = 0.5163*(60-55.5) + 151 = 153

Example 2

If the concentration of O_3 at 8 hours average is 0.080 ppm, the calculation of O_3 sub-index is as follows:

API for $O_3 = \left(\frac{150-101}{0.095-0.076}\right) \times (X - 0.076) + 101$ = 2450*(0.080-0.076) + 101 = 110

5.0 Status of Air Quality based on API

The API tells the public about the levels of air pollution and provides recommended actions and health advices. The index is numbered as 0–500 and divided by seven breakpoints or band to provide the details of air pollution levels in a simple way:

- 0-50 (Good)
- 51-100 (Moderate)
- 101-150 (Unhealthy for sensitive group)
- 151-200 (Unhealthy)
- 201-300 (Very Unhealthy)
- >301 (Hazardous)

It also can be presented in colour and shape code as shown in Table 4. The shape is included along with the colour code to allow easy accessibility for colour blind individuals. Whenever the API exceeds 100, the reporting of API will expand to all major news media with health notification to the media especially for specific sensitive group (Table 5). It should be noted that the concentration at which moderate levels turn into unhealthy is usually based on the ambient air quality standards. Hence, as the ambient air quality standards are moving towards more stringent guidelines, particularly for $PM_{2.5}$, API values may increase but not necessarily reflect poorer air quality compared to previous years.

Table 4 Descriptor, colour and shape for Malaysian API to indicate health level concern

Air Quality Index (API) Values	Levels of Health Concern	Colours	Shapes
0 to 50	Good	Green	
51 to 100	Moderate	Yellow	
101 to 150	Unhealthy for Sensitive Groups	Orange	
151 to 200	Unhealthy	Orange	
201 to 300	Very Unhealthy	Red	
>300	Hazardous	Maroon	

Table5: Pollutant specific sensitive groups

When this pollutant has an index above100…	Report these Sensitive Group
Ozone	People with lung disease, children, older adults, and people who are active outdoors are the groups most at risk
$PM_{2.5}$	People with heart or lung disease, older adults, children, and people of lower socioeconomic status (SES) are the groups most at risk
PM_{10}	People with heart or lung disease, older adults, children, and people of lower socioeconomic status are the groups most at risk
CO	People with heart disease are the group most at risk
SO_2	People with asthma, children, and older adults are the groups most at risk People with asthma, children, and older adults are the groups most at risk

APPENDIX 3

New Malaysia Ambient Air Quality Standard

New Ambient Air Quality Standard was established in order to replace the older Malaysia Ambient Air Quality Guideline that has been used since 1989.
The New Ambient Air Quality Standard adopts 6 air pollutants criteria that include 5 existing air pollutants which are particulate matter with the size of less than 10 micron (PM10), sulfur dioxide (SO2), carbon monoxide (CO), nitrogen dioxide (NO2), and ground level ozone (O3) as well as 1 additional parameter which is particulate matter with the size of less than 2.5 micron (PM2.5).
The air pollutants concentration limit will be strengthen in stages until 2020. There are 3 interim targets set which include interim target 1 (IT-1) in 2015, interim target 2 (IT-2) in 2018 and the full implementation of the standard in 2020.

Table 1a : New Malaysia ambient air quality standard the concentrations of all pollutants are in μgm^{-3} except for co (mgm^3)

Pollutants	Averaging Time	Unit	Ambient Air Quality Standard		
			IT-1 (2015)	IT-2 (2018)	Standard (2020)
Particulate Matter with the size of lessthan 10 micron (PM_{10})	1 Year	$\mu g/m^3$	50	45	40
	24 Hour	$\mu g/m^3$	150	120	100
Particulate Matter with the size of lessthan 2.5 micron ($PM_{2.5}$)	1 Year	$\mu g/m^3$	35	25	15
	24 Hour	$\mu g/m^3$	75	50	35
SulfurDioxide (SO_2)	1 Hour	$\mu g/m^3$	350	300	250
	24 Hour	$\mu g/m^3$	105	90	80
Nitrogen Dioxide (NO_2)	1 Hour	$\mu g/m^3$	320	300	280
	24 Hour	$\mu g/m^3$	75	75	70
Ground Level Ozone (O_3)	1 Hour	$\mu g/m^3$	200	200	180
	8 Hour	$\mu g/m^3$	120	120	100
CarbonMonoxide (CO)	1 Hour	mg/m^3	35	35	30
	8 Hour	mg/m^3	10	10	10

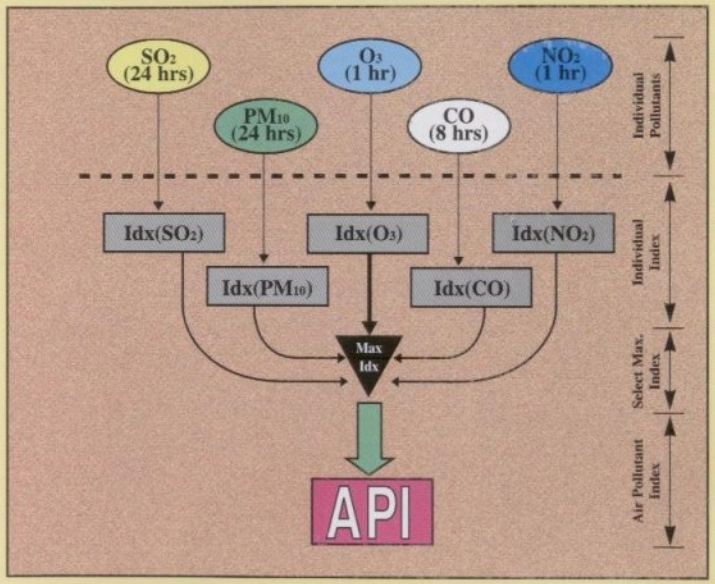
Table 1b: New Malaysia Ambient Air Quality Standard. The concentrations of gases is in part per million (ppm)

Pollutants	Averaging Time	Unit	Ambient Air Quality Standard		
			IT-1 (2015)	IT-2 (2018)	Standard (2020)
Particulate Matter with the size of lessthan 10 micron (PM_{10})	1 Year	µg/m3	50	45	40
	24 Hour	µg/m3	150	120	100
Particulate Matter with the size of lessthan 2.5 micron ($PM_{2.5}$)	1 Year	µg/m3	35	25	15
	24 Hour	µg/m3	75	50	35
SulfurDioxide (SO_2)	1 Hour	ppm	0.13	0.11	0.10
	24 Hour	ppm	0.04	0.03	0.03
Nitrogen Dioxide (NO_2)	1 Hour	ppm	0.17	0.16	0.15
	24 Hour	ppm	0.04	0.04	0.04
Ground Level Ozone (O_3)	1 Hour	ppm	0.10	0.10	0.09
	8 Hour	ppm	0.06	0.06	0.05
CarbonMonoxide (CO)	1 Hour	ppm	30	30	26
	8 Hour	ppm	9	9	9

*The conversionassumes an ambient pressure of 1 atmosphere and a temperature of 25 °C

APPENDIX 4

A GUIDE TO AIR POLLUTANT INDEX IN MALAYSIA
(API)



DEPARTMENT OF ENVIRONMENT

1997

A GUIDE TO AIR POLLUTANT INDEX IN MALAYSIA
(API)

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MALAYSIA

1997

First Edition 1993
Second Edition 1996
Third Edition 1997

ACKNOWLEDGMENT

The Department of Environment wishes to acknowledge the contributions by the following organisations in producing this publication:

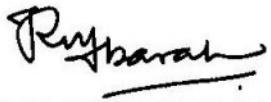
(i) Universiti Putra Malaysia
(ii) Alam Sekitar Malaysia Sdn Bhd

FOREWORD

The Air Pollutant Index (API) is established to provide easily understandable information about air pollution to the public. Its predecessor was the Malaysian Air Quality Index (MAQI) which was developed after a study done by the University Pertanian Malaysia in 1993. In line with the need for regional harmonisation and for easy comparison with the countries in ASEAN, the API was adopted in 1996. The API follows closely the Pollutant Standard Index (PSI) developed by the United States Environmental Protection Agency (US-EPA).

Air pollution levels are determined using internationally recognised ambient air quality measuring techniques. The pollutants measured which include sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone and suspended particulate matters of less than ten microns in size are considered health related pollutants. API is then computed using the technique developed by US-EPA.

With the publication of this information booklet, I hope the public will have a better understanding of the API. Last but not least, I would like to acknowledge with thanks the contributions by University Putra Malaysia, ASMA Sdn Bhd and all those who have contributed towards the publication of this booklet.



HAJAH ROSNANI IBARAHIM
Director-General of Environmental Quality
Malaysia.

A GUIDE TO AIR POLLUTANT INDEX IN MALAYSIA

Introduction

In 1989, the Department of Environment (DOE) formulated a set of air quality guidelines, termed Recommended Malaysian Air Quality Guidelines (RMG) for air pollutants, defining the concentration limits of selected air pollutants which might adversely affect the health and welfare of the general public. Based on the RMG, the Department subsequently developed its first air quality index system, known as the Malaysian Air Quality Index (MAQI) in 1993. An index system plays an important role in conveying to both decision-makers and the general public the status of ambient air quality, ranging from good to hazardous. Application of the index system, particularly in industrialised countries, has demonstrated its useful role in providing a sound basis for both the effective management of air quality, as well as the effective protection of public health.

In line with the need for regional harmonisation and for easy comparison with countries in the region, the Department revised its index system in 1996, and the Air Pollutant Index (API) was adopted. The API system of Malaysia closely follows the Pollutant Standard Index (PSI) system of the United States.

Air Pollutant Index (API)

Recommended Malaysian Air Quality Guidelines

An air pollution index system normally includes the major air pollutants which could cause potential harm to human health should they reach unsafe levels. The air pollutants included in Malaysia's API are ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and suspended particulate matter of less than 10 microns in size (PM10).

Generally, an air pollution index system is developed in easily understood ranges of values, instead of using the actual concentrations of air pollutants, as a means for reporting the quality of air or level of air pollution. To reflect the status of the air quality and its effects on human health, the ranges of index values could then be categorised as follows: good, moderate, unhealthy, very unhealthy and

hazardous. The index values may also be categorised according to episode or action criteria, such as air pollutant levels within stipulated standards, or levels signifying conditions for alert, warning, emergency and significant harm. The key reference point in these air pollution index systems is the index value of 100 (the "safe" limit), which is based on the National Air Quality Standards or Guidelines for the specific air pollutants concerned.

The Recommended Malaysian Air Quality Guidelines (RMG) which form the basis for calculating the API are presented in **Table 1**. These guidelines have been derived from available scientific and human health data, and basically represent "safe levels" below which no adverse health effects have been observed. The RMG are generally comparable to the corresponding air quality standards recommended by the World Health Organisation and other countries.

The averaging time, which varies from 1 to 24 hours for the different air pollutants in the RMG, represents the period of time over which measurements is monitored and reported for the assessment of human health impacts of specific air pollutants. As such, the air pollution indices are normally monitored and reported for the same averaging times as those employed for the air quality standards/guidelines.

API

As mentioned earlier, the API system closely follows the PSI system of the United States. As such, the API breakpoints at 100 for the various air pollutants correspond to the respective RMG concentrations regarded as being "safe levels". In other words, air quality with API values exceeding 100 are considered likely to cause health effects to the general public. Further, a linear correlation is assumed from API 0 to API 100, with the breakpoint at API 50 corresponding to 50% of the RMG concentration standards for the various air pollutants.

Breakpoints at API 200, 300, 400 and 500 directly mirror those of the PSI system of the United States. Figures 1 to 5 depict the sub-index functions of the five API pollutants involved, which are used as the basis for calculating the API. The respective breakpoints and their corresponding episode category descriptors are also indicated. The relevant equations for the calculation of API values for the various concentration segments are also presented in Figures 1 to 5. The corresponding API values calculated as a function of the air pollutant

concentrations are listed in Table 3. Further, air quality in terms of human health impacts and implications are categorised as follows under the API system adopted in Malaysia:

API	DESCRIPTOR
0 - 50	good
51 - 100	moderate
101 - 200	unhealthy
201 - 300	very unhealthy
>300	hazardous

Table 4 summarises additional information on general human health effects and cautionary statements within each of the API categories.

Following the requirements of the RMG from the standpoint of human health implications, the API values are reported for varying averaging time as follows: PM10 and SO_2 on 24-hour running averages, CO on 8-hour running averages and O_3 and NO_2 on 1-hour running averages. The API for PM10 (based on a 24-hour period running average), reflects specifically levels of suspended particulate matter pollution and it may not be linked directly to visibility factors, as visibility is often determined by results of semi-quantitative observations over relatively shorter time periods.

How Is the Air Pollutant Index Calculated?

To determine the API for a given time period, the sub-index values (sub-API) for all five air pollutants included in the API system are first calculated using the above mentioned sub-index functions for the air quality data collected from the Continuous Air Quality Monitoring Stations. The corresponding air quality data are subjected to the necessary quality control processes and quality assurance procedures, prior to the sub-index calculations.

The API value reported for a given time period represents the highest API value among all the sub-APIs calculated during that particular time period. The predominant parameter contributing towards a particular API value is normally indicated alongside the API value. For example, during the 1997 haze episode, the predominant air pollutant parameter was PM10 and hence the API values reported were primarily based on the PM10 sub-index.

This approach is also adopted by the PSI system of the United States, and is also commonly followed by other countries in an effort to promote a uniform and comparable API system. Ideally, all sub-API values exceeding the API 100 threshold limit should also be reported in addition to the predominant API value *per se*.

The following is an outline of the procedures involved in calculating the API values (process flow chart is shown in Figure 6):-

(i) Collect continuous air quality data for the five air pollutants in the API system for sufficient averaging time periods;

(ii) Conduct the necessary calibration, validation, quality control and quality assurance in the process of data collection;

(iii) Calculate average concentration of the specific air pollutants for the specified averaging time periods;

(iv) Calculate sub-index value for each of the five air pollutants based on the average concentrations calculated and with the use of the sub-index functions (Figures 1-5);

(v) Report the API at a given time for the preceding averaging period (taking the common end point of 1-hour, 8-hour or 24-hour for all five pollutants) in terms of the highest sub-index value obtained; i.e.

API = Max {sub-indices of all five air pollutants}

State the specific air pollutant responsible for the API value as the predominant parameter along with the index;

State the relevant health effect category of the API reported;

Report also other sub-indices, if any, which exceed 100 (thereby indicating violation of an RMG).

(vi) An example of graphically presenting the air quality in terms of the API, that can be used for reporting in the TV media, is shown in Figure 7. The shaded segments may be represented by successive colours of the spectrum: "good" (blue); "moderate" (green); "unhealthy" (yellow); "very unhealthy" (orange); "hazardous" (red). This would give a subjective impression of a gradual worsening of the air pollution problem with each descriptor category.

Table 1: Recommended Malaysia Air Quality Guidelines (at 25°C and 101.13 kPa) adopted in Air Pollutant Index calculation

POLLUTANT	AVERAGING TIME	MALAYSIA GUIDELINES	
		(ppm)	($\mu g/m^3$)
OZONE	1 Hour	0.10	200
CARBON MONOXIDE #	8 Hour	9	10
NITROGEN DIOXIDE	1 Hour	0.17	320
SULFUR DIOXIDE	24 Hour	0.04	105
PM10	24 Hour		150

mg/m^3

Table 2: Significant Harm Level to API value of 500

Pollutant and Averaging Time	Concentration	
	($\mu g/m^3$)	(ppm)
Carbon Monoxide (CO) 8 hr	57,500	50
Nitrogen Dioxide (NO_2) 1 hr	3,700	2.0
Ozone (O_3) 1 hr	1,200	0.60
Particulate Matter (PM10) 24 hr	600	-
Sulfur Dioxide (SO_2) 24 hr	2,620	1.0

Table 3: API values, in steps of 5, from 5 to 500

API	Gravimetric Units					Volumetric Units			
	CO mg/m3	O3 µg/m3	SO2 µg/m3	NO2 µg/m3	PM10 µg/m3	CO ppm	O3 ppm	SO2 ppm	NO2 ppm
5	0.50	10	5.25	16.00	5.00	0.45	0.005	0.002	0.009
10	1.00	20	10.50	32.00	10.00	0.90	0.010	0.004	0.017
15	1.50	30	15.75	48.00	15.00	1.35	0.015	0.006	0.026
20	2.00	40	21.00	64.00	20.00	1.80	0.020	0.008	0.034
25	2.50	50	26.25	80.00	25.00	2.25	0.025	0.010	0.043
30	3.00	60	31.50	96.00	30.00	2.70	0.030	0.012	0.051
35	3.50	70	36.75	112.00	35.00	3.15	0.035	0.014	0.060
40	4.00	80	42.00	128.00	40.00	3.60	0.040	0.016	0.068
45	4.50	90	47.25	144.00	45.00	4.05	0.045	0.018	0.077
50	5.00	100	52.50	160.00	50.00	4.50	0.050	0.020	0.085
55	5.50	110	57.75	176.00	60.00	4.95	0.055	0.022	0.094
60	6.00	120	63.00	192.00	70.00	5.40	0.060	0.024	0.102
65	6.50	130	68.25	208.00	80.00	5.85	0.065	0.026	0.111
70	7.00	140	73.50	224.00	90.00	6.30	0.070	0.028	0.119
7.	7.50	150	78.75	240.00	100.00	6.75	0.075	0.030	0.128
80	8.00	160	84.00	256.00	110.00	7.20	0.080	0.032	0.136
85	8.50	170	89.25	272.00	120.00	7.65	0.085	0.034	0.145
90	9.00	180	94.50	288.00	130.00	8.10	0.090	0.036	0.153
95	9.50	190	99.75	304.00	140.00	8.55	0.095	0.038	0.162
100	10.00	200	105.00	320.00	150.00	9.00	0.100	0.040	0.170
105	10.35	210	139.75	360.50	160.00	9.30	0.105	0.053	0.192
110	10.70	220	174.50	401.00	170.00	9.60	0.110	0.066	0.213
115	11.05	230	209.25	441.50	180.00	9.90	0.115	0.079	0.235
120	11.40	240	244.00	482.00	190.00	10.20	0.120	0.092	0.256
125	11.75	250	278.75	522.50	200.00	10.50	0.125	0.105	0.278
130	12.10	260	313.50	563.00	210.00	10.80	0.130	0.118	0.299
135	12.45	270	348.25	603.50	220.00	11.10	0.135	0.131	0.321
140	12.80	280	383.00	644.00	230.00	11.40	0.140	0.144	0.342
145	13.15	290	417.75	684.50	240.00	11.70	0.145	0.157	0.364
150	13.50	300	452.50	725.00	250.00	12.00	0.150	0.170	0.385
155	13.85	310	487.25	765.50	260.00	12.30	0.155	0.183	0.407
160	14.20	320	522.00	806.00	270.00	12.60	0.160	0.196	0.428
165	14.55	330	556.75	846.50	280.00	12.90	0.165	0.209	0.450
170	14.90	340	591.50	887.00	290.00	13.20	0.170	0.222	0.471
175	15.25	350	626.25	927.50	300.00	13.50	0.175	0.235	0.493
180	15.60	360	661.00	968.00	310.00	13.80	0.180	0.248	0.514
185	15.95	370	695.75	1008.50	320.00	14.10	0.185	0.261	0.536
190	16.30	380	730.50	1049.00	330.00	14.40	0.190	0.274	0.557
195	16.65	390	765.25	1089.50	340.00	14.70	0.195	0.287	0.579
200	17.00	400	800.00	1130.00	350.00	15.00	0.200	0.300	0.600

CO is measured as an 1 hr average, O3 and NO2 are 1-hr averages, SO2 and PM10 are 24-hr averages

(continued)

API	Gravimetric Units					Volumetric Units			
	CO mg/m3	O3 µg/m3	SO2 µg/m3	NO2 µg/m3	PM10 µg/m3	CO ppm	O3 ppm	SO2 ppm	NO2 ppm
205	17.85	420	840	1187	353.50	15.75	0.210	0.315	0.630
210	18.70	440	880	1243	357.00	16.50	0.220	0.330	0.660
215	19.55	460	920	1300	360.50	17.25	0.230	0.345	0.690
220	20.40	480	960	1356	364.00	18.00	0.240	0.360	0.720
225	21.25	500	1000	1413	367.50	18.75	0.250	0.375	0.750
230	26.25	505	1005	1469	372.5	23.75	5.25	5.375	5.75
235	22.95	540	1080	1526	374.50	20.25	0.270	0.405	0.810
240	23.80	560	1120	1582	378.00	21.00	0.280	0.420	0.840
245	24.65	580	1160	1639	381.50	21.75	0.290	0.435	0.870
250	25.50	600	1200	1695	385.00	22.50	0.300	0.450	0.900
255	26.35	620	1240	1752	388.50	23.25	0.310	0.465	0.930
260	27.20	640	1280	1808	392.00	24.00	0.320	0.480	0.960
265	28.05	660	1320	1865	395.50	24.75	0.330	0.495	0.990
270	28.90	680	1360	1921	399.00	25.50	0.340	0.510	1.020
275	29.75	700	1400	1978	402.50	26.25	0.350	0.525	1.050
280	30.60	720	1440	2034	406.00	27.00	0.360	0.540	1.080
285	31.45	740	1480	2091	409.50	27.75	0.370	0.555	1.110
290	32.30	760	1520	2147	413.00	28.50	0.380	0.570	1.140
295	33.15	780	1560	2204	416.50	29.25	0.390	0.585	1.170
300	34.00	800	1600	2260	420.00	30.00	0.400	0.600	1.200
305	34.80	810	1625	2297	424.00	30.50	0.405	0.610	1.220
310	35.20	820	1650	2334	428.00	31.00	0.410	0.620	1.240
315	35.80	830	1675	2371	432.00	31.50	0.415	0.630	1.260
320	36.40	840	1700	2408	436.00	32.00	0.420	0.640	1.280
325	37.00	850	1725	2445	440.00	32.50	0.425	0.650	1.300
330	37.60	860	1750	2482	444.00	33.00	0.430	0.660	1.320
335	38.20	870	1775	2519	448.00	33.50	0.435	0.670	1.340
340	38.80	880	1800	2556	452.00	34.00	0.440	0.680	1.360
345	39.40	890	1825	2593	456.00	34.50	0.445	0.690	1.380
350	40.00	900	1850	2630	460.00	35.00	0.450	0.700	1.400
355	40.60	910	1875	2667	464.00	35.50	0.455	0.710	1.420
360	41.20	920	1900	2704	468.00	36.00	0.460	0.720	1.440
365	41.80	930	1925	2741	472.00	36.50	0.465	0.730	1.460
370	42.40	940	1950	2778	476.00	37.00	0.470	0.740	1.480
375	43.00	950	1975	2815	480.00	37.50	0.475	0.750	1.500
380	43.60	960	2000	2852	484.00	38.00	0.480	0.760	1.520
385	44.20	970	2025	2889	488.00	38.50	0.485	0.770	1.540
390	44.80	980	2050	2926	492.00	39.00	0.490	0.780	1.560
395	45.40	990	2075	2963	496.00	39.50	0.495	0.790	1.580
400	46.00	1000	2100	3000	500.00	40.00	0.500	0.800	1.600

CO is measured as an 1 hr average, O3 and NO2 are 1-hr averages; SO2 and PM10 are 24-hr averages

(continued)

API	Gravimetric Units					Volumetric Units			
	CO mg/m3	O3 µg/m3	SO2 µg/m3	NO2 µg/m3	PM10 µg/m3	CO ppm	O3 ppm	SO2 ppm	NO2 ppm
405	46.58	1010	2126	3038	505.00	40.50	0.505	0.810	1.620
410	47.15	1020	2152	3075	510.00	41.00	0.510	0.820	1.640
415	47.73	1030	2178	3113	515.00	41.50	0.515	0.830	1.660
420	48.30	1040	2204	3150	520.00	42.00	0.520	0.840	1.680
425	48.88	1050	2230	3188	525.00	42.50	0.525	0.850	1.700
430	49.45	1060	2256	3225	530.00	43.00	0.530	0.860	1.720
435	50.03	1070	2282	3263	535.00	43.50	0.535	0.870	1.740
440	50.60	1080	2308	3300	540.00	44.00	0.540	0.880	1.760
445	51.18	1090	2334	3338	545.00	44.50	0.545	0.890	1.780
450	51.75	1100	2360	3375	550.00	45.00	0.550	0.900	1.800
455	52.33	1110	2386	3413	555.00	45.50	0.555	0.910	1.820
460	52.90	1120	2412	3450	560.00	46.00	0.560	0.920	1.840
465	53.48	1130	2438	3488	565.00	46.50	0.565	0.930	1.860
470	54.05	1140	2464	3525	570.00	47.00	0.570	0.940	1.880
475	54.63	1150	2490	3563	575.00	47.50	0.575	0.950	1.900
480	55.20	1160	2516	3600	580.00	48.00	0.580	0.960	1.920
485	55.78	1170	2542	3638	585.00	48.50	0.585	0.970	1.940
490	56.35	1180	2568	3675	590.00	49.00	0.590	0.980	1.960
495	56.93	1190	2594	3713	595.00	49.50	0.595	0.990	1.980
500	57.50	1200	2620	3750	600.00	50.00	0.600	1.000	2.000

CO is measured as an 1 hr average, O3 and NO2 are 1-hr averages; SO2 and PM10 are 24-hr averages

Table 4: Comparison of API values with level of pollution and health measures.

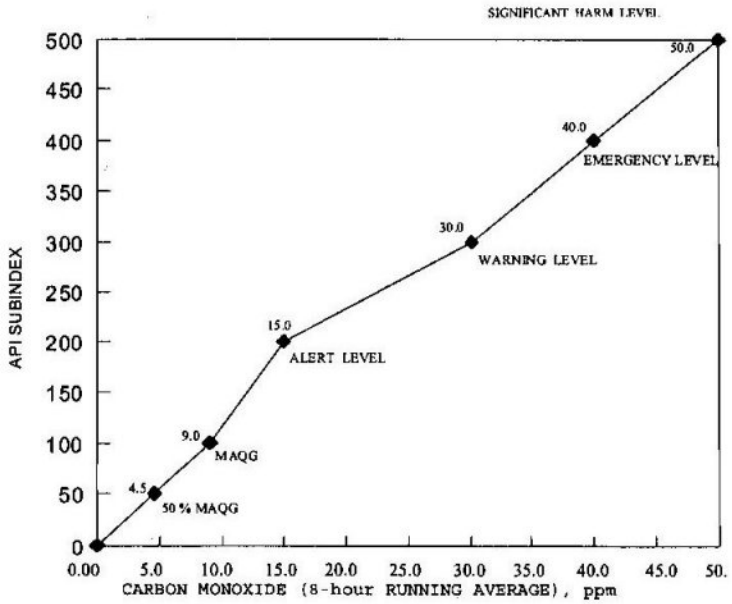
API	Status	Level of Pollution	Health Measures
0 - 50	Good	Pollution low and has no ill effects on health.	✡ No restriction of activities for all groups of people. ✡ To practice healthy lifestyle e.g. not to smoke, exercise regularly and to observe proper nutrition.
51 - 100	Moderate	Moderate pollution and has no ill effects on health	✡ No restriction of activities for all groups of people. ✡ To practice healthy lifestyle e.g. not to smoke, exercise regularly and to observe proper nutrition.
101-200	Unhealthy	Mild aggravation of symptoms among high risk persons, i.e. those with heart or lung disease.	✡ Restriction of outdoor activities for high risk persons. ✡ General population should reduce vigorous outdoor activity.

Table 4: continued

API	Status	Level of Pollution	Health Measures
201 - 300	Very Unhealthy	Significant aggravation of symptoms and decreased exercise tolerance in person with heart or lung disease.	✡ Elderly and persons with known heart or lung disease should stay indoors and reduce physical activity. ✡ General population should avoid vigorous outdoor activity ✡ Those with any health problems to consult doctor.
301 - 500	Hazardous	Severe aggravation of symptoms and endangers health.	✡ Elderly and persons with existing heart or lung disease should stay indoors and reduce physical activity. ✡ General population should avoid vigorous outdoor activity
Above 500	Emergency	Severe aggravation of symptoms and endangers health.	✡ General population advised to follow the orders of the National Security Council and always to follow the announcements through the mass media.

Source: Ministry of Health, Malaysia.

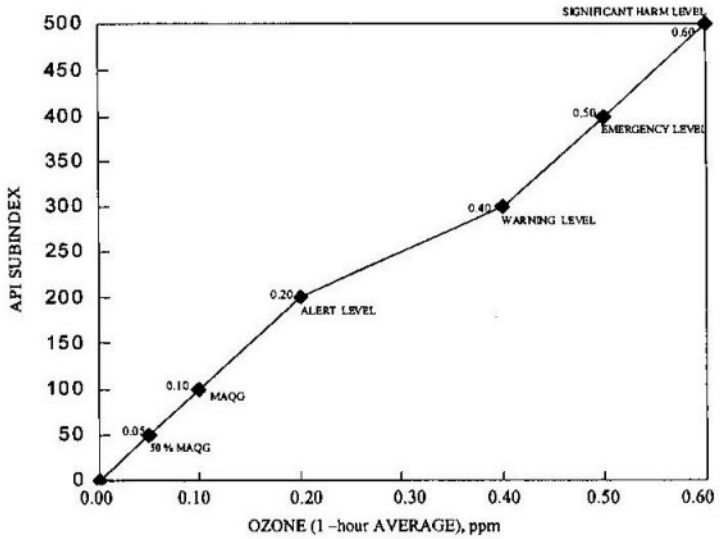
Figure 1 : API subindex function for carbon monoxide



Equation for the calculation of API based on 8– hour average concentration:

conc < 9 ppm	API = conc. x 11.11111
9 < conc. < 15	API = 100 + {[conc. – 9] x 16.66667}
15 < conc. < 30	API = 200 + {[conc. – 15] x 6.66667}
conc. > 30 ppm	API = 300 + {[conc. – 30] x 10}

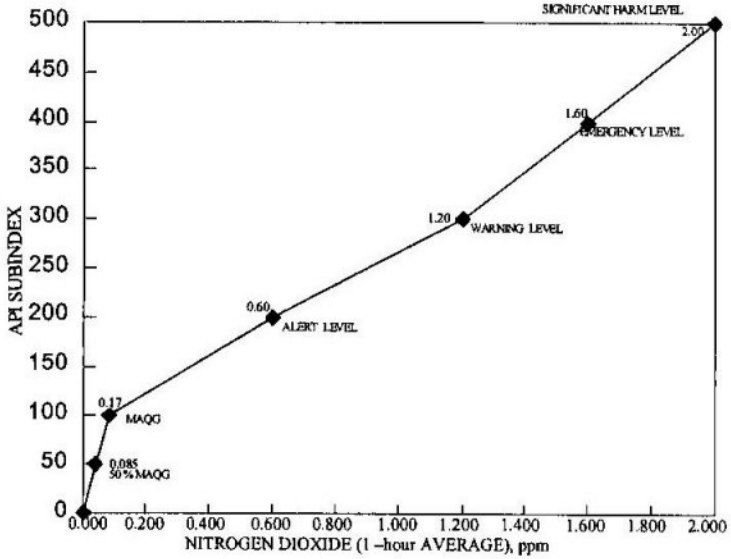
Figure 2 : API subindex function for ozone



Equation for the calculation of API based on 1– hour average concentration:

*conc < 0.2 ppm	API = conc. x 1000
0.2 < conc. < 0.4	API = 200 + {[conc. – 0.2] x 500}
conc. > 0.4 ppm	API = 300 + {[conc. – 0.4] x 1000}

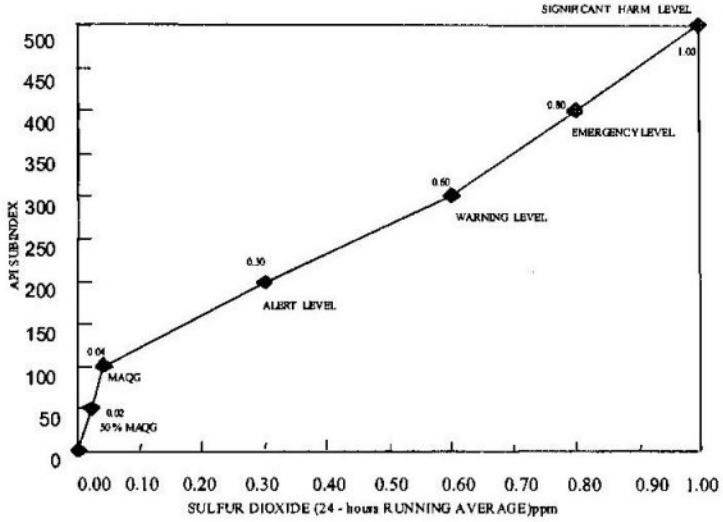
Figure 3 : API subindex function for nitrogen dioxide



Equation for the calculation of API based on 1– hour average concentration:

*conc < 0.17 ppm	API = conc. x 588.23529
*0.17 < conc. < 0.6	API = 100 + {[conc. – 0.17] x 232.56}
0.6 < conc. < 1.2	API = 200 + {[conc. – 0.6] x 166.667}
conc. > 1.2 ppm	API = 300 + {[conc. – 1.2] x 250}

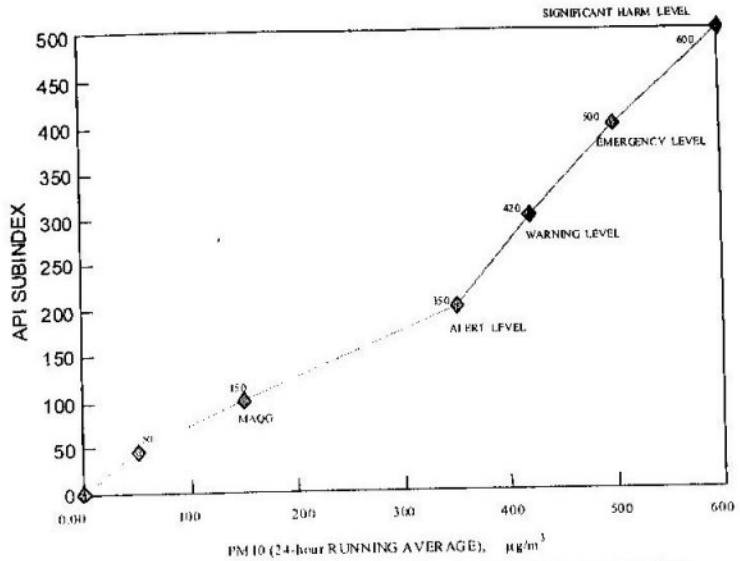
Figure 4 : API subindex function for sulfur dioxide



Equation for the calculation of API based on 24 – hour average concentration:

*conc < 0.04 ppm	API = conc. x 2500
*0.04 < conc. < 0.3	API = 100 + {[conc. – 0.04] x 384.61}
0.3 < conc. < 0.6	API = 200 + {[conc. – 0.3] x 333.333}
conc. > 0.6 ppm	API = 300 + {[conc. – 0.6] x 500}

Figure 5 : API subindex function for PM10



Equation for the calculation of API based on 24 – hour average concentration:

conc < 50 µg/cu.m	API = conc.
50 < conc. < 350	API = 50 + {[conc. – 50] x 0.5}
350 < conc. < 420	API = 200 + {[conc. – 350] x 1.4286}
420 < conc. < 500	API = 300 + {[conc. – 420] x 1.25}
conc. > 500 µg/cu.m	API = 400 + [conc. – 500]

Figure 6: Air Pollutant Index Process Flowchart

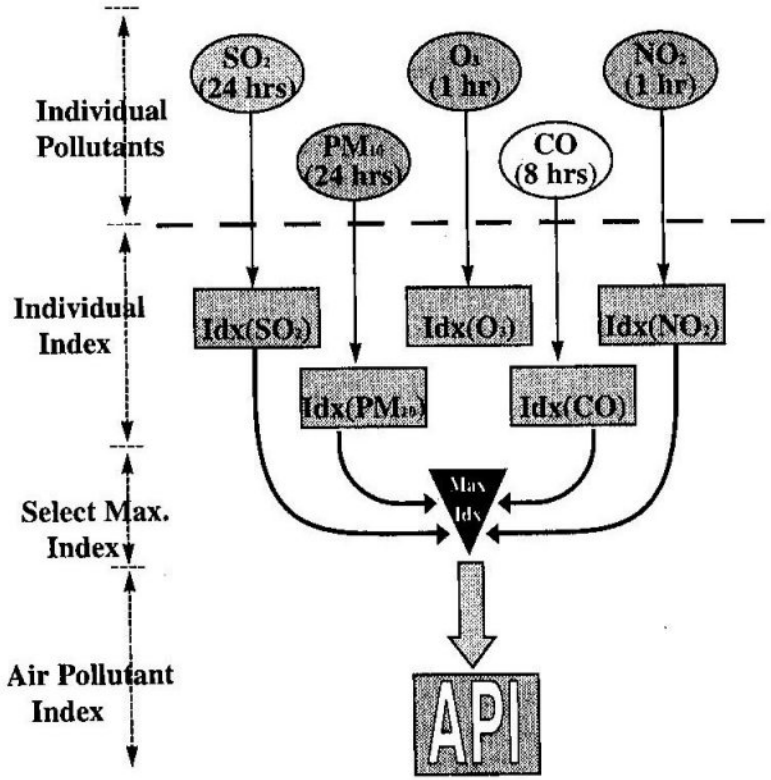
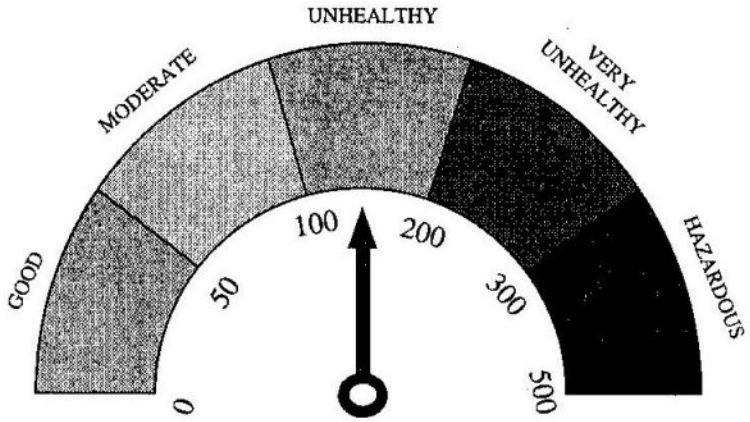


Figure 7: Example of possible API report for television.



POLLUTANT: Ozone

TODAY'S HEALTH IMPLICATION:
Mild aggravation of symptoms among high risk persons, i.e. those with heart or lung disease.