5 Air Pollution and Health in Malaysia

Mazrura Sahani, Md Firoz Khan, Wan Rozita Wan Mahiyuddin, Mohd Talib Latif, Chris Fook Sheng Ng, Mohd Famey Yussoff, Amir Afiq Abdullah, Er Ah Choy, Norhayati Mohd Tahir

CONTENTS

5.1 Background ........................................................................................................... 97
  5.1.1 General Information about the Country and Cities .......................................... 97
  5.1.2 Trends and Episodes of Air Pollution ............................................................... 100
5.2 Health Effects ....................................................................................................... 103
  5.2.1 Acute Health Effects of Criteria Air Pollutants ........................................ 104
  5.2.2 Health Effects of Haze Air Pollution .............................................................. 104
5.3 Exposures .............................................................................................................. 105
  5.3.1 Measurement of Air Pollutants in Malaysia .................................................. 105
  5.3.2 Exposure Assessment ....................................................................................... 105
5.4 Risk Assessment and Management ....................................................................... 107
  5.4.1 Source Identification of Particulate Matter .................................................... 107
  5.4.2 Economic Burden ............................................................................................ 108
  5.4.3 Air Quality Management in Malaysia ............................................................. 108
  5.4.4 Clean Air Action Plan ..................................................................................... 109
  5.4.5 Issues and Challenges .................................................................................... 110
  5.4.6 Strategies and Actions Taken .......................................................................... 111
  5.4.7 Moving Forward: Air Pollution and Low-Carbon Initiatives ....................... 112
5.5 Conclusions ............................................................................................................ 112
References .................................................................................................................. 112

5.1 BACKGROUND

This chapter contains an overview of air pollution and health in Malaysia. It aims to provide general information about Malaysia and the major cities, past trends and episodes of air pollution, measurement of exposure, and epidemiological studies of air pollution in Malaysia and the air quality management in the country.

5.1.1 General Information about the Country and Cities

Malaysia is located on in the center of Southeast Asia surrounded by the South China Sea, Malacca Straits, and the Sulu Sea. The country is crescent-shaped, starting with
Peninsular Malaysia (West Malaysia) and extending to Sabah and Sarawak (East Malaysia), located on the island of Borneo.

Malaysia covers an area of about 330,803 square kilometers, consisting of 11 states in Peninsular Malaysia—namely Johor, Kedah, Kelantan, Malacca, Negeri Sembilan, Pahang, Perak, Perlis, Penang, Selangor, and Terengganu—and the federal territories of Kuala Lumpur and Putrajaya, Sabah and Sarawak on the island of Borneo, and the federal territory of Labuan off Sabah (Economic Planning Unit [EPU], 2013).

Malaysia lies entirely in the equatorial zone with the characteristic features of the climate of Malaysia, which are uniform temperature, high humidity, and copious rainfall (Malaysian Meteorological Department [MMD], 2015b). The average rainfall is around 250 centimeters (98 inches) a year and the average daily temperature throughout Malaysia varies from 21°C to 32°C. The climates of the peninsula and East Malaysia differ, as the climate on the peninsula is directly affected by wind from the mainland, as opposed to the more maritime weather of the east (MMD, 2015a). Due to the location and its influence by the Pacific Ocean, Malaysia is exposed to the El Niño effect, which reduces rainfall in the dry season. Change of climate is likely to have a significant effect on Malaysia, increasing sea levels and rainfall, increasing flooding risks and leading to large droughts.

Malaysia’s 2010 mid-year population is estimated to be 30.34 million. Population structure in Malaysia in terms of the ethnic group is comprised of Malay (50.1%), Chinese (22.6%), Indigenous (11.8%), Indian (6.7%), Others (0.7%), and noncitizens (8.2%). The distribution of the number of urban centers by population size class for the states in Malaysia showed that Selangor by far had the highest number of urban centers in the country, followed by Johor and Perak. In the metropolitan category—that is, population size class of 75,000 persons and above—Selangor

![Map of Malaysia](image)

FIGURE 5.1 Map of Malaysia.
Air Pollution and Health in Malaysia
topped the list with 10 urban centers. In 2000, all states, with the exception of Perlis and Melaka, had more than half of their urban population in the size class of 75,000 persons and above.

Beginning in 1971 through the late 1990s, Malaysia transformed itself from a producer of raw materials into an emerging multisector economy. Growth was almost exclusively driven by exports—particularly of electronics. As a result, Malaysia was hard-hit by the global economic downturn and the slump in the information technology (IT) sector in 2001 and 2002. Gross domestic product (GDP) in 2001 grew only 0.5% due to an estimated 11% contraction in exports, but a substantial fiscal stimulus package equal to USD 1.9 billion mitigated the worst of the recession and the economy rebounded in 2002 with a 4.1% increase. The economy grew 4.9% in 2003, notwithstanding a difficult first half, when external pressures from severe acute respiratory syndrome (SARS) and the Iraq War led to caution in the business community. Growth topped 7% in 2004. Healthy foreign exchange reserves, low inflation, and a small external debt are all strengths that would minimize the risks of Malaysia experiencing a future financial crisis similar to the one in 1997. The economy remains dependent on continued growth in the United States, China, and Japan, top export destinations and key sources of foreign investment.

Klang Valley is the most urbanized region in Malaysia. This Klang Valley region (Figure 5.2) consists of the federal territory of Kuala Lumpur and the Selangor districts of Gombak, Petaling, Hulu Langat, and Klang and several local authorities, including three important councils: namely Kuala Lumpur City Hall, Shah Alam City Council, and Petaling Jaya City Council. This complex conurbation known as Kuala Lumpur conurbation (KLC) developed historically through the progressive development of satellite towns from Kuala Lumpur, especially after World War II. In the early 1970s, Klang Valley was acknowledged as a coherent urban planning region (Katiman, 1997). Despite its small area of about 242.3 square kilometers, which is approximately 1.25% of the size of Malaysia, the region’s population represents

FIGURE 5.2 Map of Klang Valley region with Kuala Lumpur and its conurbation.
17.4% of the national population. Kuala Lumpur, located in the Klang Valley region, comprises the highest density of population, with 5,639 persons per square kilometer. Since the Kuala Lumpur Structure Plan (KLSP) 1984 (KL, 2020), the other urban centers in the Klang Valley region, notably Petaling Jaya, Shah Alam, and Subang Jaya, have grown at a rate that far outstrips that of the city. There has been strong in-migration to the KLC outside Kuala Lumpur from all over the country and net out-migration from Kuala Lumpur into residential areas located outside the city. In the year 2000, the population of Kuala Lumpur was approximately 1.42 million, compared with 4.30 million for the whole of the KLC, a population distribution pattern not envisaged by the KLSP 1984 (KL, 2020).

While the Klang Valley only covers a small proportion of Malaysia, its economic activity contributes greatly to the national GDP. Kuala Lumpur’s economy originally developed around the processing of locally produced tin and rubber, food products, and traditional handicrafts, but these sectors became less prominent as Malaysia’s efforts to develop a more industrialized and export-oriented economy have created new industries in and around Kuala Lumpur. Kuala Lumpur City plays as the premier financial and commercial center in Malaysia. In addition, the employment to population ratio for Kuala Lumpur City is higher if compared with Malaysia as a whole. This shows that Kuala Lumpur City is an important generator of jobs. The three most important subsectors in terms of employment for Kuala Lumpur today are finance, insurance, real estate, and the business services sector (24.2%), followed by wholesale and retail trade, the restaurant and hotel sector, (17.2%) and finally the government services sector (15.1%). This highlights the dominance of producer services supplied by Kuala Lumpur. The government services sector retains a high percentage, but this has changed as many of the federal ministries have shifted to Putrajaya. In the KLC, the three most important employment subsectors are manufacturing (19.8%), followed by finance, insurance, real estate, and business services sector (18.2%), and thirdly personal services (15.2%). This also highlights the growth in the industrial sector in the KLC outside the Kuala Lumpur City center, particularly to the southern part known as Langat River Basin (Er et al., 2013).

5.1.2 Trends and Episodes of Air Pollution

The environmental regulatory agency in Malaysia is the Department of Environment (DoE), under the Ministry of Natural Resources and the Environment. The DoE monitors the country’s ambient air quality through a network of 52 continuous monitoring stations, currently through a concessionaire agreement with Alam Sekitar Malaysia Sdn Bhd (ASMA). These monitoring stations are strategically located in both residential and industrial areas to detect any significant change in the air quality which may be harmful to human health and the environment. The National Air Quality Monitoring Network is also supplemented by manual air quality monitoring stations (high-volume air samplers) located at 14 different sites. In addition, MMD monitors selected air quality parameters from a total of 22 stations, mostly located at airports, and some distance away from urban centers across Peninsular Malaysia and East Malaysia.
Parameters monitored by the DoE stations include particulate matter with diameter less than 10 micrometers (PM$_{10}$) and several heavy metals such as lead are measured once every 6 days. The major gaseous air pollutants monitored include ozone (O$_3$), sulfur dioxide (SO$_2$), nitrogen oxides (NO$_x$), and carbon monoxide (CO). In the case of MMD stations, parameters monitored include rainwater acidity, aerosols (total suspended particulate [TSP] and PM$_{10}$), and in the Petaling Jaya station, atmospheric O$_3$ (monitoring of vertical O$_3$-profile and total column O$_3$). Most of these air stations are colocated with climatological stations (wind speed, wind direction, temperature, relative humidity, solar radiation, etc.) so that simultaneous and continuous observation of both meteorological and air pollution parameters are carried out. This would ensure that a comprehensive data set comprised of both air quality and meteorological data would be available for assessment of any air pollution event. Furthermore, several other academic institutions are involved in investigating air quality, chemical speciations, and their health concerns.

In general, overall air quality in Malaysia is at a level of good to moderate for most of the time. However, like other countries in the Southeast Asia region, Malaysia also has a fair share of poor air quality episodes. Air pollution in Malaysia is unique by its nature. Seasonal, episodic and transboundary air pollution has been observed for many years. Poor air quality in Malaysia was first associated with the haze of April 1983, which caused severe disruption to daily life. The exact cause of this haze episode was uncertain; however, it has been widely attributed to forest fires from neighboring countries as well as local sources such as agricultural waste burnings, peat soil fires, and fuel combustions from industries and vehicles. Since then, the haze has recurred almost every year, in particular during southwesterly (June to September) and northeasterly (December to March) monsoons with major prolonged episodes recorded in 1991, 1992, 1997, 2003, 2005, and 2013.

Dominick et al. (2012) analyzed the air quality data (CO, NO$_2$, SO$_2$, PM$_{10}$ and O$_3$) obtained from eight DoE monitoring stations across Malaysia during the 2008–2009 period. They reported that average and maximum concentrations recorded during this period were well below the Recommended Malaysian Air Quality Guideline (RMAQG). Main sources of emissions identified were from motor vehicles, aircraft, industries, and the areas of high population density. Azmi et al. (2010) conducted a long-term trend and status of air quality in Klang Valley from 1997 to 2006 using secondary data obtained from the DoE. They found that the concentrations of CO, NO$_2$, and SO$_2$ were mainly influenced by heavy traffic while PM$_{10}$ and O$_3$ were predominantly related to regional tropical factors, such as the influence of biomass burning and of ultraviolet radiation from sunlight with possible local sources (Figure 5.3).

Ahamad et al. (2014) also corroborated the above finding where they reported that the O$_3$ pattern in the Klang Valley area is strongly influenced by local pollutant emission and dispersion characteristic. Latif et al. (2012) reported that a high surface O$_3$ concentration is usually observed between January and April, while a low surface O$_3$ concentration is found between June and August. Analysis of daily variations in surface O$_3$ and the precursors, NO, NO$_2$, CO, nonmethane...
hydrocarbon (NMHC), and Ultraviolet b (UVb), indicated that the surface $O_3$ photochemistry in this study area exhibits a positive response to the intensity and wavelength in UVb while being influenced by the concentration of NOx, particularly through titration processes.

A study to determine the temporal distribution and chemical characteristics of coarse and fine particulate matter had been conducted in Kuala Terengganu, on the eastern coast of Peninsular Malaysia (Mohd Tahir et al., 2013). They reported that levels of fine (FP: mean = 14.3 ± 6.5) and coarse (CP: mean = 10.4 ± 5.4) particles observed in this city were lower than those reported for the Kuala Lumpur during nonhaze days by Hamzah et al. (2000) (mean FP = 30.9 ± 14.4; mean CP = 24.5 ± 21.1). However, the %FP to PM$_{10}$ was similar, accounting for 58% and 56% for Kuala Terengganu and Kuala Lumpur, respectively.
In addition to the effect of dominant pollution sources, the pattern of local and regional meteorology greatly influences the variability of air pollution in this country. A study by Latif et al. (2014) showed that the meteorological parameters play an important role in air pollution variability. They are closely associated with pollutant concentrations as they influence pollutant dispersion and chemical reactions in photosensitive reactions. Further, precisely the variability of PM$_{10}$ concentration in Malaysia can be decomposed into four dominant modes as described by Juneng et al. (2009): (1) southwest coastal region of the Malaysian Peninsula with the PM$_{10}$ showing a peak concentration during the summer monsoon, that is, when the winds are predominantly southerly or south-westerly, and a minimal concentration during the winter monsoon; (2) the region of western Borneo with the PM$_{10}$ exhibiting a concentration surge in August–September, which is likely to be the result of the northward shift of the intertropical convergence zone (ITCZ) and the subsequent rapid arrival of the rainy season; (3) the northern region of the Malaysian Peninsula with strong bimodality in the PM$_{10}$ concentration (seasonally, this component exhibits two concentration maxima during the late winter and summer monsoons, as well as two minima during the intermonsoon periods); and (4) the northern Borneo region, which exhibits weaker seasonality of the PM$_{10}$ concentration.

The chemical profiles of the reduced visibility were featured by unique characteristics. The concentrations of organic compounds were observed to be greater during the hazy situation than other periods in a year and some of them are suspected to have transported from neighboring areas (Abas and Simoneit, 1996). As an indicator of major organic fraction in atmospheric aerosol, particle-bound polycyclic aromatic hydrocarbons (PAHs) are semivolatile, carcinogenic, and persistent organic pollutants (POPs). A recent study by Jamhari et al. (2014) showed that substantial contributions from traffic emission and a minimal influence from coal combustion and natural gas emissions were observed to the concentrations of PAHs. Surfactants, one of the surface active agents and organic species, are present in the atmospheric aerosol of Kuala Lumpur. The dominant sources of surfactants were motor vehicles, soil/road dust, biomass burning, and sea spray (Wahid et al., 2013).

### 5.2 HEALTH EFFECTS

Like many developing nations, air pollution is a serious health risk in Malaysia following many years of rapid industrialization and economic growth since independence. To curb air pollution and improve air quality, the Environmental Quality Act (EQA) 1974 and the Environmental Quality (Clean Air) Regulation were introduced in 1978 to control emissions from industry (i.e., power plants and industrial processes) and automobiles, which constitute the major sources of air pollution in urban areas (Afroz et al., 2003). The law also explicitly prohibits open burning, as it exacerbates the problem of haze in the region. Other laws related to air pollution include the Food Act 1983, which controls air pollution from tobacco smoke in public venues; Road Transport Act 1987/Environmental Quality (Control of Emission from Diesel Engine) Regulation 1996, which regulate emission of black smoke by motor vehicles;
5.2.1 **Acute Health Effects of Criteria Air Pollutants**

Earliest findings on the acute health effects of air pollutants in Malaysia came from a retrospective time-series study conducted in Klang Valley, the most populated region of Malaysia (Jamal et al., 2004). The study was conducted to quantify short-term health risks associated with daily exposure to the five criteria air pollutants (i.e., PM$_{10}$, CO, SO$_2$, NO$_2$, and O$_3$). Health endpoints investigated were the respiratory (International Classification of Diseases 10th Revision [ICD10]: J00–J99) and cardiovascular (ICD10: I10–I99) disease-related hospital admissions and nonaccident mortality based on discharge data from two public hospitals (Hospital Kuala Lumpur and Hospital Selayang) and two university hospitals (Hospital Universiti Kebangsaan Malaysia and University Malaya Medical Centre) during the period from January 1, 2000, to December 31, 2003. The study used Poisson general additive model to estimate the relative risk (RR) of daily morbidity and mortality cases for each criteria air pollutant, with adjustment to temporal component, maximum temperature, and rainfall via smoothing function, and day-of-the-week effect via dummy coding. Delayed effects of temperature and rainfall up to the previous 3 days were also adjusted. Single-day effect up to 3 preceding days (lag 3) and cumulative effect using 3- and 5-day moving averages were computed for the first, second (median), and third quartile increments in the concentration of air pollutant. The study reported significant effects of PM$_{10}$, NO$_2$, SO$_2$, CO, and O$_3$ on respiratory and cardiovascular disease-related hospital admissions for adults and children in all four hospitals based on single-pollutant models. Premature mortality due to the short-term exposure to NO$_2$, SO$_2$, and O$_3$ was also noted. A study that investigated the association between short-term exposure to air pollutants and natural mortality in the Klang Valley region reported significant forward displacement of all-cause mortality as a result of exposure to PM$_{10}$ and O$_3$ (Wan Mahiyuddin et al., 2013). The study found statistically significant effect of PM$_{10}$ at lag 1 (RR = 1.0099, 95% confidence interval [CI] = 1.009–1.0192) and 5-day cumulative effect of O$_3$ (RR = 1.0215, 95% CI = 1.0013–1.0202). Given the longer study period of 2000–2006 and that the study was based on mortality statistics from the national database, which captured all mortality cases in the population, statistical power was relatively higher than the previous study that based its findings on the discharge data of four hospitals.

5.2.2 **Health Effects of Haze Air Pollution**

Despite the various regulations, air pollution remains a public health hazard in Malaysia, with numerous studies reporting adverse health effects of exposure to atmospheric pollutants. Early studies were mostly related to the 1997 Southeast Asian haze, which was due to the widespread open biomass burnings to clear agricultural land and forest in Kalimantan and Sumatra. These large-scale forest and plantation fires caused thick smoky haze over a large portion of Southeast Asia, especially Indonesia, Malaysia, and Singapore (Sastry, 2002), as confirmed via satellite
images (Lim and Ooi, 1998) and analysis of local monitoring data that linked this severe haze episode to high concentration of PM$_{10}$ up to 20-fold beyond the limit recommended by the Malaysian Air Quality Guideline (MAQG, 1989), in spite of the relatively low levels of other gaseous pollutants such as CO$_2$, NO$_2$, SO$_2$, and O$_3$ compared with the normal nonhaze days (Awang et al., 2000; Noor, 1998).

During the 1997 haze, Hospital Kuala Lumpur, a government tertiary referral hospital, recorded a substantial increase in cases of upper respiratory tract infections, conjunctivitis, and asthma, with a 2-day delayed effect for asthma incidences (Awang et al., 2000). A similar acute trend was observed in other major hospitals in Kuala Lumpur, Sarawak, and neighboring Singapore (Brauer and Hisham-Hashim, 1998), leading to the supposition that instead of other gaseous pollutants, the observed adverse health effects were attributable to the short-term exposure of PM$_{10}$, the predominant air contaminant during haze (Awang et al., 2000; DoE, 2000). A panel study examining the respiratory function of 107 children found statistically significant decreases of lung function in these children measured between the nonhaze period a year earlier and the haze period in 1997 (Hashim et al., 1998). Another study that used a matched control group to compare the pulmonary functions of 16-year-old schoolchildren exposed to different levels of PM$_{10}$ (i.e., 103 $\mu$g/m$^3$ vs. 47 $\mu$g/m$^3$ in the control group) documented significant reduction in spirometry parameters among those with higher long-term exposure to PM$_{10}$ (Awang et al., 2000). More recently, the health effects of haze events occurring between 2000 and 2007 in the Klang Valley region were examined using a case-crossover design with time-stratified referent selection (Sahani et al., 2014). Haze events were defined using a cutoff of PM$_{10}$ concentration at 100 $\mu$g/m$^3$ based on time-series and backward trajectory analyses. The study reported significant 2-day delayed effect of haze event on all-cause mortality among children less than 14 years of age (odds ratio [OR] = 1.41, 95% CI = 1.01–1.99). Effects of haze events on respiratory mortality were immediate (i.e., current-day, lag 0) (OR = 1.19, 95% CI = 1.02–1.40). This immediate effect on respiratory mortality was particularly discernible among elderly males over 60 years old (OR = 1.41, 95% CI = 1.09–1.84).

5.3 EXPOSURES

5.3.1 Measurement of Air Pollutants in Malaysia

The major air pollutants, for example, TSP, PM$_{10}$, O$_3$, SO$_2$, NOx, and CO, are measured by in-situ monitoring instruments in Malaysia. The TSP, PM$_{10}$, and trace gases along with other meteorology-related variables (e.g., wind speed, wind direction, temperature, relative humidity, solar radiation) are monitored by DoE. The details of the methods and instruments used are shown in Table 5.1.

5.3.2 Exposure Assessment

Distributions of PM$_{10}$, O$_3$, SO$_2$, NOx, CO, volatile organic compounds (VOCs), as well as heavy metals can be interpreted using synoptic scale wind pattern, cluster of trajectory analysis, as well as local wind direction by the Grid Analysis and Display
Multivariate receptor models are very useful tools in the studies of source apportionment of pollutants at urban or local scale. The application of receptor model in principle translates the research results to be used into policy. To introduce control measures, it is necessary to know the source information of pollutants in the amendment of the regulations. Thus, the receptor modeling procedures solely involved in prediction of sources and the contribution of the respective source factor. Several models are widely used by the distinguished researchers for the quantitative information of the pollutant sources. The most commonly used models are (1) chemical mass balance model (CMB) (Watson et al., 1990), (2) positive matrix factorization (PMF) (Paatero and Tapper, 1994), (3) UNMIX (Henry, 1987), and (4) principal component analysis coupled with absolute principal component score (PCA/APCS) (Thurston and Spengler, 1985). Among the receptor models, PMF uses weighted least-squares fit and estimates error of the measured data and can impose nonnegativity constraints. Moreover, the prior source information or prior knowledge of pollutants is not necessary, which is the first and foremost advantage of this procedure. Therefore, the PMF is considered to be used in the apportionment of pollutant sources. Two input files as concentrations of variables and uncertainty of the data are needed to proceed with PMF. The detailed of preparing the uncertainty data file has given in the FMF 3.0 Fundamentals and User Guide by USEPA.

### TABLE 5.1
Lists of Instruments Used by Department of Environment (DoE) Monitoring Air Quality in Malaysia

<table>
<thead>
<tr>
<th>Variables</th>
<th>Instrument (Teledyne, US)</th>
<th>Measurement Principal</th>
<th>Precision</th>
<th>Detection Limit (DL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_3$</td>
<td>Analyzer 400A</td>
<td>Chemiluminescence</td>
<td>0.5% (&lt;10s)</td>
<td>0.04 ppm</td>
</tr>
<tr>
<td>NO, NO$_2$, NO$_x$</td>
<td>Advanced pollution instrumentation (API) 200A</td>
<td>Chemiluminescence</td>
<td>0.5%</td>
<td>0.4 ppb</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>API M100A</td>
<td>Florescence</td>
<td>0.5%</td>
<td>0.4 ppb</td>
</tr>
<tr>
<td>CO</td>
<td>API M300</td>
<td>Nondispersive infrared absorption (NDIR)</td>
<td>0.5% (&lt;10s)</td>
<td>0.04 ppm</td>
</tr>
<tr>
<td>CH$_4$</td>
<td>API M4020</td>
<td>Flame ionization detector (FID)</td>
<td>1%</td>
<td>—</td>
</tr>
<tr>
<td>NmHC</td>
<td>API M4020</td>
<td>FID</td>
<td>1%</td>
<td>—</td>
</tr>
<tr>
<td>TSP</td>
<td>High volume air sampler (HVAS)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>Beta attenuation monitor (BAM) 1020</td>
<td>Met-One beta attenuation</td>
<td>—</td>
<td>&lt;1.0 $\mu$g m$^{-3}$ (24 h)</td>
</tr>
</tbody>
</table>
Principal component analysis (PCA) is a statistical technique which takes in the form of eigenvector analysis (Khan et al., 2010). Absolute PCA coupled with multiple linear regression (APCS-MLR) is an advanced version as compared with basic PCA-MLR procedure (Khan et al., 2010; Thurston and Spengler, 1985). The major difference between APCS-MLR and PCA-MLR is in the ability to perform zero correction in the APCS-MLR compared with PCA-MLR. The zero correction reduces the negative indices in the factor scores derived from PCA procedure. Else, a comparison is to be made using PMF 3.0, a robust USEPA developed PMF model, and PCA/APCS as these two receptor modelings are capable of extracting robust source information of pollutants at any local scale.

The dataset to be used in the above receptor modeling procedures needs to undergo a series of pretreatment. The measurement or monitoring data always contain noisy or bad data, outliers, missing and value below detection limit. Prior to feeding into the prescribed models, the data variables are to be cleaned up with proper deletion/replacement procedures acknowledged by peer journals.

5.4 RISK ASSESSMENT AND MANAGEMENT

5.4.1 Source Identification of Particulate Matter

Although numerous studies have established the link between atmospheric particulate matter and adverse health effects in Malaysia, for effective control of air particulate pollutant, information on the sources that contribute to the composition of PM$_{10}$ and its toxicity is important. The earliest work on the chemical characterization and source apportionment of particulate matter based on 1-year monitoring in Klang Valley in 1997–1998 reported that fine particle (particulate matter with size less than 2.5 micron [PM$_{2.5}$]) was the dominant particulate pollutant with level during haze days four to five times higher than that during nonhaze days. Elemental composition revealed both natural and anthropogenic contribution with biomass burning as the primary source during episodes of haze (Hamzah et al., 2000). Another study at Kuala Terengganu, a coastal city east of Malaysian Peninsula, from August 2006 to December 2007 reported that measured chemical species accounted for about 54% and 32% of coarse and fine particle on average, respectively, with the remaining possibly consisting of organic and carbonaceous materials (Mohd Tahir et al., 2013). The study also identified soil dust, marine aerosol, vehicle exhaust, secondary aerosol, traffic aerosol (e.g., nonengine combustion such as tire, clutch, and brake wear), and biomass burning (e.g., garden wastes, use of wood as fuel, and use of palm fiber and shell waste as boiler fuel at the many palm oil mills) as the main sources of PM pollution in the region. A recent study at Bangi, a semiurban area, focusing on heavy metals reported Fe as the dominant element in PM$_{10}$, followed by Zn and Pb, which were all often associated with traffic emissions, both vehicular and non-engine combustion sources. Earth crust and road dust were the main sources of PM$_{10}$ in the region, followed by vehicle emissions (Wahid et al., 2014). These findings on the chemical mixture and sources of PM are important as they allow further epidemiological work to assess the health impact of specific PM components, instead of the general total-mass-based measure, and can provide
important feedback to the current monitoring guideline. A study by Afroz et al. (2003) suggests that the air pollution comes mainly from land transportation, industrial emissions, and open burning sources. Among them, land transportation contributes the most to air pollution.

5.4.2 Economic Burden

Estimates of economic loss due to the health impacts of haze have also been reported. A study reported a country-wide incremental cost of MYR 5.02 million (about USD 1.51 million) for treatment of haze-related diseases, including self-medication, and MYR 4.3 million for productivity losses (about USD 1.29 million) as a result of the 1997 haze pollution (Othman and Mohd Shahwashid, 1999). This study included population at risk from all states in the country except the haze-free states such as Kelantan, Terengganu, and Pahang. The estimation took into consideration the various intensities and length of haze within the August–October period. A more recent economic assessment of haze-related illnesses based on the daily inpatients from four major hospitals in Kuala Lumpur and the surrounding area reported an estimated annual loss of USD 91,000 due to acute exposure to transboundary smoke haze pollutions that occurred in 2005, 2006, 2008, and 2009 (Othman et al., 2014). The figure was expected to go up if outpatient treatment, subsequent productivity loss, and shortage of hospital beds were considered.

5.4.3 Air Quality Management in Malaysia

The EQA, the basic framework for environmental management in Malaysia, was enacted in 1974. The Act was officially endorsed by the Government of Malaysia in its Third Malaysia Plan (1981–1985). The main environmental regulatory agency in Malaysia at the federal level is DoE, which is currently part of the Ministry of Natural Resources and the Environment. It was established to administer and enforce EQA of 1974 (Heng and Looi, 2002).

The Malaysian government plays a very important role in addressing the issues of air pollution. The Malaysian government has already foreseen the importance of managing and tackling the air pollution problems in the country, as these issues have been stated in the two, 9th and 10th, Malaysia Plans (Rancangan Malaysia Ke [RMK]). In the 9th Malaysia Plan, a Clean Air Action Plan (CAAP) was developed and implemented to improve air quality (Abdullah et al., 2012). In the RMK10, some initiatives will be introduced to address climate change through the adoption of strategies to protect economic growth and development factors from the impact of climate change as well as mitigation strategies to reduce the emission of greenhouse gases (EPU, 2010).

The Malaysian government established MAQGs, the Air Pollutant Index (API), and the Haze Action Plan to improve air quality. The Malaysian DoE formulate policy development using the RMAQG 1989 as shown in Table 5.2.

Furthermore, Malaysian DoE introduced API in mitigating the effect of air pollutants as it is an indicator for the air quality status at any particular area. API
Air Pollution and Health in Malaysia

is calculated based on the five criteria air pollutants, which are SO₂, NO₂, CO, PM₁₀, and ground-level O₃. The API and its health effect threshold are described in Table 5.3.

5.4.4 CLEAN AIR ACTION PLAN

The CAAP is drawn up in line with the “7th Green Strategy” in the National Policy on the Environment. The CAAP presents a set of strategies and indicators that together provide a roadmap to achieve better air quality by reducing the frequency, severity, and duration of poor air quality episodes.

The strategies and measures listed in this plan are aimed at managing air quality through close cooperation between government, private sectors, and nongovernmental organizations (NGOs). The time frame of this CAAP is categorized based on its priorities, that is, short term (immediate or less than 2 years), medium term (2–5 years), and long term (5–10 years). This plan is a living document; as new technologies and approaches become available, they would be incorporated into the plan.

In the implementation of the CAAP, apart from achieving good air quality it also generates co-benefit in terms of reduction in greenhouse gas emissions. Major contributors of greenhouse gas emissions that are addressed in the plan include emissions from motor vehicles and industries, haze due to land and forest fires, and open burning activities.

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Malaysian Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Averaging</td>
</tr>
<tr>
<td>Ozone (O₃)</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td>8 hours</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td>8 hours</td>
</tr>
<tr>
<td>Nitrogen dioxide (NO₂)</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
</tr>
<tr>
<td>Sulfur dioxide (SO₂)</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td>24 hours</td>
</tr>
<tr>
<td>Particulate matter with diameter less than 10 micrometer (PM₁₀)</td>
<td>24 hours</td>
</tr>
<tr>
<td></td>
<td>12 months</td>
</tr>
<tr>
<td>Total suspended particulate (TSP)</td>
<td>24 hours</td>
</tr>
<tr>
<td></td>
<td>12 months</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>3 months</td>
</tr>
</tbody>
</table>

* mg m⁻³
Poor air quality is mainly caused by combustion of fossil and other fuels by industries, motor vehicles, and households. Open burning and forest fires also contribute to poor air quality. Pollutants and hazardous matters are either emitted directly or as the result of chemical reactions of emissions such as ground-level $O_3$.

The main air pollutants are PM$_{10}$, NO$_2$, SO$_2$, CO, O$_3$, and VOCs that will post a wide range of negative health impacts such as lung and heart malfunctions, bronchitis and asthma. Inadequate urban planning, the establishment of satellite cities and the preference of individual over public transport result in increasing motor vehicle usage which in turn increases the level of air pollution in urban areas. Low quality of fuel and outdated emission standards further exacerbate the problem. The challenge is to move toward environmentally sustainable transport. Environmentally sustainable transport could result in a number of co-benefits such as reduced air pollution, traffic congestion, and oil usage that improves environmental quality and human health.

### TABLE 5.3

<table>
<thead>
<tr>
<th>API</th>
<th>Status</th>
<th>Health Effect</th>
<th>Health Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–50</td>
<td>Good</td>
<td>Low pollution without any bad effect on health.</td>
<td>No restriction for outdoor activities to the public. Maintain healthy lifestyle.</td>
</tr>
<tr>
<td>51–100</td>
<td>Moderate</td>
<td>Moderate pollution that does not pose any bad effect on health.</td>
<td>No restriction for outdoor activities to the public. Maintain healthy lifestyle.</td>
</tr>
<tr>
<td>101–200</td>
<td>Unhealthy</td>
<td>Worsen the health condition of high-risk people, who are the people with heart and lung complications.</td>
<td>Limited outdoor activities for the high-risk people. Public need to reduce the extreme outdoor activities.</td>
</tr>
<tr>
<td>201–300</td>
<td>Very unhealthy</td>
<td>Worsen the health condition and low tolerance of physical exercises to people with heart and lung complications.</td>
<td>Old and high-risk people are advised to stay indoors and reduce physical activities. People with health complications are advised to see doctor.</td>
</tr>
<tr>
<td>&gt;300</td>
<td>Hazardous</td>
<td>Hazardous to high-risk people and public health.</td>
<td>Old and high-risk people are prohibited from outdoor activities. Public are advised to prevent from outdoor activities.</td>
</tr>
<tr>
<td>&gt;500</td>
<td>Emergency</td>
<td>Hazardous to high-risk people and public health.</td>
<td>Public are advised to follow orders from National Security Council and always follow the announcement in mass media.</td>
</tr>
</tbody>
</table>
Industries without adequate control measures, the use of poor quality fuel and the lack of land-use planning, thus allowing heavy polluting industries to be sited in urban dwelling centers, also contribute to poor air quality. Large-scale and uncontrolled fires resulting from open burning of biomass release significant amounts of pollutants into the atmosphere, including fine dusts, CO, carbon dioxide, and so on. Such fires could result in haze episodes, thus affecting public health and the environment.

5.4.6 Strategies and Actions Taken

The strategies and some of the actions taken in CAAP are outlined into five categories as below:

1. Motor vehicles emission reduction
   Motor vehicles are one of the main contributors to the air pollution in the country, particularly in urban areas. Several strategies and actions had been planned and implemented to reduce motor vehicle emission.

2. Industrial emission reduction
   The air pollutants emitted from the industrial sector come from various sources such as power plants, industrial energy use, and large-scale industries such as iron and steel plants and cement industries. Several strategies and actions had been planned and implemented to reduce industrial emission.

3. Prevention and control of haze due to land/forest fire and open burning activities
   Several strategies to prevent and control haze pollution at local and regional levels had been planned and implemented.

4. Knowledge enhancement
   Knowledge enhancement aims to establish a scientific and progressive society that is capable, advanced, innovative and forward-looking that contributes to the scientific and technological civilization of the future.

   Under this initiative, the DoE has recently engaged a team of experts on various aspects of atmospheric science from universities and other research institutes, NGOs and private sectors to review the existing Malaysian Ambient Air Quality Guideline. As a result, a new Malaysian Ambient Air Quality Standard has been proposed with an inclusion of a new air parameter, particulate matter with size less than 2.5 micron (PM$_{2.5}$) in addition to existing parameters (PM$_{10}$, CO, SO$_2$, NO$_2$, and ground-level O$_3$) where their values have been reviewed and revised.

5. Public awareness and participation
   Public support could be achieved through well-informed citizens who are aware and fully committed. Several strategies to enhance public awareness and participation, among others, are to enhance education and awareness for specific target groups at different levels, improve air quality dissemination and feedback mechanism, close partnership at community-based levels, NGO and private sectors, corporate social responsibility and outreach programs to address air pollution issues.
5.4.7 MOVING FORWARD: AIR POLLUTION AND LOW-CARBON INITIATIVES

Malaysia recognizes the threat of climate change and has implemented the National Policy on Climate Change (2009) and the National Green Technology Policy (2009) in order to adapt the economy to the low-carbon pathway. In line with the national direction to promote climate-resilient sustainable development, numerous strategies to reduce carbon emission have been identified to avert climate change. Implementation of these low-carbon strategies are currently being studied in selected cities. These strategies to reduce carbon can also improve outdoor air quality, leading to various ancillary health benefits. A study to understand the health co-benefits of emission control is currently ongoing at Iskandar, a designated low-carbon development region in the southernmost tip of Peninsular Malaysia which is undergoing tremendous economic growth. By linking climate change mitigation measures to environmental health, the study hopes to provide additional justification for strict emission cut backs and help stakeholders and policy makers to prioritize mitigation actions against the background of finite resources and time.

5.5 CONCLUSIONS

In this chapter, professionals from various backgrounds have collaborated to construct an overview of air pollution and health in Malaysia. Overall air quality in Malaysia is generally at a level of good to moderate for most of the time. However, like other countries in the Southeast Asia region, Malaysia is also experiencing recurrent haze almost every year, in particular during southwesterly and northeasterly monsoons. Numerous studies have established the link between atmospheric particulate matter and adverse health effects in Malaysia. Further research on the sources that contribute to the composition of PM$_{10}$ and haze pollution is necessary to determine in detail the toxicological effects of local air pollution and haze episodes in Southeast Asia. The air pollution and health risk analysis are important in developing comprehensive decision-support tools in air quality management. The Malaysian government plays a very important role in managing the air quality and has established the RMAQ and the clean air and haze action plan. International cooperation aimed at reducing biomass burning, which could lead to significant public health benefits for Malaysia and other Southeast Asian countries, is really needed for the benefit of people in Southeast Asia.

REFERENCES


Economic Planning Unit. 2013. The Malaysian economy in figures. EPU, Prime Minister’s Department, Malaysia.


