Overview of Health Impacts due to Haze Pollution in Johor, Malaysia

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Abstract. Haze pollution is one of the major environmental issues caused by aerosols, having brought about a history of heavy smog pollution events like the London smog in 1952 and the Los Angeles smog in the 1960s. However, in Malaysia, haze events are attributed to forest and peat fires in Kalimantan and Southern Sumatra, Indonesia. The burned biomass basically contains concentrated particulate matters that are hazardous to health among susceptible population groups. Based on the extensive literature review conducted, the small number of available local studies on the health effects of air pollution in Malaysia conducted so far focused on air pollution sciences. In this paper, a comprehensive overview of studies done on the impacts of haze on health conditions among populations in Malaysia is presented. The result shows that the number of upper respiratory tract infection cases was directly proportional to the particulate matter concentration and Air Pollution Index value in Johor in the years 2014 and 2015. Particulate matter is the major contributor in the formation of heavy hazes and is more likely to initiate detrimental health effects compared to other inhalable particles due to their size, large area, and strong activity, making them more likely to carry harmful substances causing a higher number of infected patients with upper respiratory tract infections.

Keywords: *air pollution; haze; health impact; particulate matter; peat fire; public health.*

1 Introduction

Haze is defined as the presence of fine particles (0.1-1.0 µm in diameter) dispersed at a high concentration through a portion of the atmosphere, which diminishes horizontal visibility, giving the atmosphere a characteristic opalescent appearance [1]. Haze is most likely to occur during the months of January to February and June to August every year in Malaysia. Most recently, this happened in 2015. The air pollution index (API) readings for some areas in Malaysia even went far beyond the hazardous range. Basically, the Malaysian Air Pollution Index standard, established by the Department of Environmental

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(DOE), is as follows: good (0-50), moderate (51-100), unhealthy (101-200), very unhealthy (201-300) and hazardous (greater than 300). Malaysia has suffered from the haze phenomenon almost every year since the last seven years, which is attributed to forest and peat fires in Indonesia. Generally, burned biomass may contribute to increased aerosol loading or smoke in the atmosphere [2].

The burned biomass contains concentrated particulate matters (PM) (organic matter, graphitic carbon, toxic metals and acidic species) that are hazardous to health, especially to the lung, heart, and circulatory systems, and may cause eye-associated illnesses among vulnerable population groups. The risks of getting heart attacks, respiratory diseases, and lung cancer are all significantly higher in people who breathe in dirty air compared to matching groups in cleaner environments [3].

In general, air pollution may cause adverse health effects among exposed receptors through several modes of contact, i.e. by inhalation, direct absorption through the skin, or contamination of food and water. A comprehensive health risk assessment has now become pertinent since such practice can serve as the basis for any re-formulation or review of the current air quality standards [4]. The presence of health symptoms, including bronchial inflammations, allergic reactions, and irritation of the mucous membranes of the eyes and nose, indicate that air pollution must be urgently reduced [5]. The World Health Organization (WHO) has estimated that 2 million children under the age of 5 die each year from acute respiratory diseases exacerbated by air pollution [3].

The small number of available local studies on the health effects of air pollution in Malaysia conducted so far, focused on air pollution sciences. Far fewer studies, however, included the specific health impacts due to haze as a subject of interest. Due to the repeated occurrence of haze events these past few years in Malaysia (2009-2015), which are getting worsen every year, this issue has received greater attention by various parties due to its adverse effects on the climate system, air quality and human health. So far, the worst was the most recent one, in 2015, as indicated by the closing of schools and API readings exceeding 300 in several places in Malaysia. This haze episode is considered the worst after the one 1997 due to the prolonged haze duration, which was more than 2 months. Due to the aforementioned concerns, it is critical to perform a study as proposed in this paper.

A comprehensive health risk assessment is now pertinent since such practice can serve as the basis for any re-formulation or review of the current air quality standards. Therefore, a detailed study on the relation between haze pollutions and the associated adverse health impacts is highly needed so that such undesired consequences on human wellbeing can be reduced (if not completely avoided), should haze episodes occur in the future.

2 Haze History in Malaysia

The chronology of hazes in Malaysia may go back to the year 1983 as the first record haze event disrupted daily life in Malaysia. Subsequently, in the year 1991, forest fires in Sumatra were said to cause very hazy weather conditions in the country. Three years later, an even more severe haze event occurred during the month of September and lasted for over a month. The main cause of the problem was identified as forest fires in Kalimantan and Southern Sumatra. Haze in Malaysia occurred again in 1997 and the dry weather and stable atmospheric conditions coupled with emissions from local pollution sources, such as motor vehicles, industries, and open burning of wastes, aggravated the situation [6]. This haze episode is considered one of the worst situations due to co-occurrence with El Niño, which prolonged the dry season that year. In recent years (2009-2015), hazes have occurred every year in Malaysia and have been getting worse from year to year with the worst one being the most recent one, in 2015. The chronology of haze incidents in Malaysia was summarized in Table 1.

Many previous studies in Malaysia have been done to identify the impacts of human activities on air quality. It was found that carbon monoxide (CO) and nitrogen dioxide (NO_2) concentrations are related to motor vehicle emissions and also to high concentrations of PM_{10} from high industrial activities and businesses around the area. However, high concentrations of PM_{10} have also been linked to the occurrence of haze from Southeast Asia, as a consequence of uncontrolled burning of forest in Indonesia [7].

Other researchers have found that increased concentrations of TSP during serious haze periods and large amounts of particulate matters were emitted and transported widely to Malaysia [8]. Based on the above findings, the main pollutant affecting the air quality in the Southeast Asia region is particulate matter (PM).

Generally, haze episodes occur during the dry season (southwest monsoon) which are drier-than-normal conditions persisting in Sumatra and the southern region of Kalimantan, often inducing large-scale and uncontrollable forest fires. The southwest monsoon (summer) is characterized by low-level southwesterly winds, commences in May and usually lasts between 3-4 months up to August. With prevailing winds blowing northwestward during this period, prolonged and large-scale forest fires in Sumatra and Kalimantan are almost certain to cause serious haze episodes in Malaysia and the greater Southeast Asian region.

Table 1 Summary of haze events in Malaysia [7].

Year	Highest API Value (Venue)	Notes
1983	No data	• First record of haze in Malaysia
1990	No data	• Total suspended particulate matter (TSP) exceeding 500 µg/m3 at certain places • Delayed in aircraft departure • Visibility up to 1.6 km
1991	No data	• Transboundary haze cause by forest fires in Kalimantan • Visibility impairment in October 1991
1994	No data	• Visibility impairment in September 1994
1997	839 (Kuching)	• Worsened by El Niño • Haze emergency declared in Sarawak • Caused by forest and peat fires • 29 continuous air quality monitoring stations (CAQMS) had PM_{10} concentrations exceeding the Malaysian Ambient Air Quality Guidelines (MAAQG) • Visibility below 0.5 km in Kuching
1998	459 (Kota Kinabalu)	• Only some places recorded high concentrations of PM_{10} and high API values, for example Kota Kinabalu, Bintulu and Klang
2005	541 (Kuala Selangor)	• Haze emergency was declared on 11 August • Some flights were suspended
2006	222 (Sri Aman)	• Moderate haze episodes in mid-July, mid-August and late September to October 2006 • 20 stations in Peninsular Malaysia recorded API values between 101-200
2009	299 (Sibu)	• Haze began in early June 2009 and progressively became worse toward July • Primary cause of this event was slash and burn practices used to clear land for agricultural purposes in Sumatra, Indonesia
2010	432 (Muar)	• Short period of haze episode from 19 to 23 October • Occurred in southern part of Peninsular Malaysia • 170 schools were closed in Muar on 21 October
2011	165 (Tanjung Malim)	• Short period of haze
2012	305 (Miri)	• Short period of haze
2013	762 (Muar)	• Short period of severe haze from 15 to 27 June 2013 due to transboundary pollution • 437 hotspots were detected in Sumatra on 21 June 2013 • The most affected areas were Johor, Melaka and Negeri Sembilan • More than 600 schools were closed in the area of Johor, where the API readings exceeded the hazardous point • A haze emergency was declared on 23 June 2013 in Muar and Ledang Districts, Johor. The haze Emergency was lifted on 24 June 2013
2014	358 (Klang)	• Short moderate haze episode • Affected areas and states were the Klang Valley, Perak, Melaka, Negeri Sembilan and Johor • Caused by forest and peatland fires in several states, namely in Selangor, Perak, Pahang, Johor, Kedah, Kelantan and Terengganu. • 203 schools in the Klang and Kuala Langat Districts in Selangor were closed as the API reached very unhealthy levels of over 200
2015	308 (Shah Alam)	• Deterioration of air quality from August to September due to massive land and forest fires in Sumatra and Kalimantan • All schools in the states of Putrajaya, Kuala Lumpur, Selangor, Negeri Sembilan, Sarawak and Melaka were closed when API reached 200 • This haze episode is considered the worst since 1997 due to the prolonged haze duration, which was more than 2 months.

Figure 1 shows the typical wind pattern over the South China Sea during the southwest monsoon.

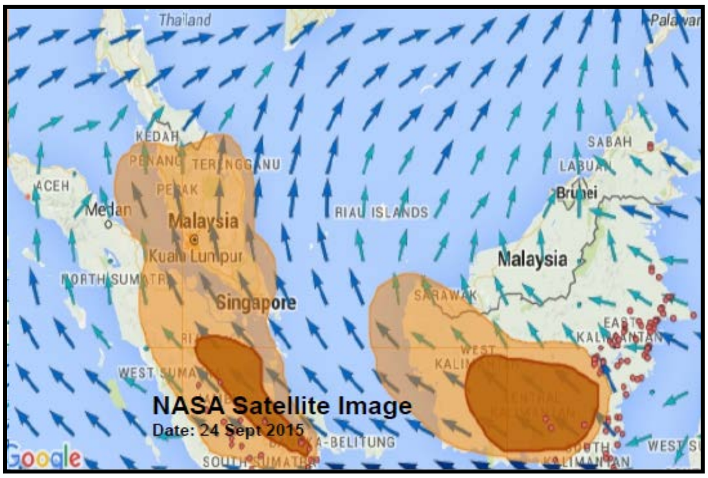

Figure 1 Climate in Malaysia during haze episodes [9].

3 Methodology

3.1 Selection of Study Area

With prevailing winds blowing north-eastward during this period, prolonged and large-scale forest fires in Sumatra and Kalimantan are almost certain to bring plumes from fires in Kalimantan to the southern part of Malaysia, especially Johor state. Therefore, this study was conducted in Johor state.

3.2 Data Needs and Sources

After the areas (locations) of the study have been decided, data collection was conducted to acquire relevant data for the study, including air quality data from Malaysian Government of Natural Resources and Environment and a database on visitation rates, health treatment (outpatients), and illness types, which were obtained from selected public hospitals and clinics.

3.2.1 Air Quality Data

Data on air quality in eight continuous air quality monitoring (CAQM) stations in Johor were obtained from the Department of Environment (DOE), which is operated by Alam Sekitar Malaysia Sdn. Bhd. (ASMA). The data consisted of mean daily ambient concentrations of particulate matter less than 10 mm (PM10) in mg/m^3, sulfur dioxide (SO_2) in ppm, nitrogen dioxide (NO_2) in ppm, ozone (O_3) in ppm, and carbon monoxide (CO) in ppm. The data were reliable and fitted the purpose of the research work since the monitoring instruments and operation protocols for the CAQM stations in Malaysia have been approved by the U.S. Environmental Protection Agency (USEPA). Quality control protocols governing fieldwork, analysis and data handling, analysis and interpretation are implemented by ASMA on a regular basis.

3.2.2 Health Clinics Outpatient Data

The monthly and annual data of morbidity for outpatients during haze and non-haze periods for health clinics were obtained from the Ministry of Health (MOH) Malaysia via the Health Informatics Center (HIC). Eight health clinics in both rural and urban areas that are located adjacent to CAQM stations were chosen. Data, including gender, age group and type of disease diagnosis, adhered to the World Health Organization's International Classification of Disease (ICD 10) for haze-related illnesses were obtained from January 2014 until 2015.

4 Cause of Haze in Malaysia

Malaysia and other Southeast Asian countries have been experiencing periodic haze episodes for decades due to forest fires on Indonesia's Sumatra Island. A large number of factors lead to these forest fires, with some being the action of oil palm plantation companies that use a slash-and-burn method to clear land to make way for oil palm plantations [10]. The responsibility lies with Indonesia although it has been suggested that MNCs from Malaysia and Singapore are involved too [11]. Another factor, mentioned by Abdul Rahman H. [10], is a natural factor, i.e. the wind, which carries the haze to Singapore and Malaysia while yet another factor is a domestic factor, caused in Malaysia itself, where human activities that release a great deal of particulate matter, such as industrial activities, motor vehicles and open burning.

Haze in Malaysia could be contributed to one common cause, as has been agreed by most ASEAN countries. Mei Mei Chu [12] reported that peat fires in Johan Setia are among the main contributors to haze occurrence in Malaysia. The peatlands are burned down in order to make the land usable for agriculture. Slash-and-burn is used where the land is used for ginger and sweet potato plantation. This is the same as what is practiced in Indonesia. Natural Resources and Environment Minister Datuk Seri Wan Junaidi Tuanku Jaafar has said in a statement that open burning always happens during the dry season [12]. On the 23rd June 2013, the Asean Specialised Meteorological Centre (ASMC) in Singapore detected 642 hotspots, scattered over parts of central and west Kalimantan. These caused the PSI reading in Singapore to reach an index of

321, where it went past the hazardous level for the first time in Singapore, surpassing the previous record of 226 in the 1997 haze episode. However, due to the wind flow, only Riau in Indonesia was hit by the haze with one of the highest PSI readings ever (900), way higher than the minimum hazard level and with a visibility of less than 500 m [10].

Abdul Rahman [10] states that since 1991, slash-and-burn pratices in Indonesia to clear land have caused significant haze. In 2013, forest fires in Riau, Indonesia burned more than 3000 hectares of plantations. In September 1997, Kuching, East Malaysia exceeded an API reading of 850, with visibility a little below 10 m. The emission from forest fires in Indonesia releases a large amount of airborne particles. Through the long-range transboundary transport of biomass emissions, haze is induced in Southeast Asia, affecting some countries severely, such as Malaysia, Singapore, Thailand and Indonesia itself. The haze is worse during the dry season, especially when these countries are hit by the El-Niño Southern Oscillation (ENSO) phenomenon [13-15].

Any air pollution episodes that occur in Singapore will occur in Malaysia too, especially in Johor due to its very close proximity. A study by Reddington, *et al*. [16] on the contribution of peat fires in Sumatra, Indonesia to the air pollution in Southeast Asia showed that the largest contribution to $PM_{2.5}$ in Singapore in October came from peat fires, with a contribution of 10.7 microg/m^3, followed by August (5.1 microg/m^3) and September (9.5 microg/m^3). During the 3rd quarter of the year, the southwest monsoon flows over Southeast Asia, where its southern part experiences an prolonged dry season, known as an El-Niño event, which triggers peat fires. In November, the northeast monsoon brings heavy rain to the region, keeping the fires away. During El-Niño Southern Oscillation (ENSO), rainfall decreases significantly, which leads to drought conditions, causing vegetation to burn [17-18]. Satellite observation shows that ENSO has a great impact on the number of fire plumes and the extension of smoke clouds over Kalimantan [19].

Reddington, *et al.* [16] mention that the Indian Ocean Dipole, IOD [20-23], could be another factor that affects the frequency and magnitude of fires in Southeast Asia and especially in Indonesia. A positive phase of IOD combined with ENSO can lead to severe drought conditions, especially in Sumatra and Kalimantan (some of the frequent hotspots of forest fires). This is similar to what happened in the episodes in 1997 [23] and 2006 [20], when severe forest fires occurred. This theory was proven through the value of the simulated total contribution of fires in October, which had a contribution that was 20 times higher than in October 2009 despite a weaker ENSO. Fires in Peninsular Malaysia and Indochina only contributed a small percentage of 2-3% to the total airborne particulate matter between 2004 and 2009, but contributed slightly more in La Niña years (4 and 12% respectively [16]). A prolonged dry season coupled with a stable atmosphere and intense emission of pollutants are ideal conditions for the formation of haze. Meteorological factors such as wind and weather further aid the formation of haze in other area, as these help the transport of pollution to other regions [10].

Fires in Southern Sumatra have largest contribution of emitted CO to Singapore (62%), which is consistent with previous observations of more than 90% on a hazy day in Singapore, which occurred when back trajectories passed over Southern Sumatra when hotspots were identified [24]. However, this is just an estimation, as it does not take the variation in atmospheric residence time into consideration, which the changes amount of airborne particulate matter.

The ongoing deforestation and expansion of palm oil plantations in Sumatra and Kalimantan, Indonesia, severely deteriorate the air quality [25-27], reducing the forest sizes in Southeast Asia by 1.45 million hectares per year [28]. Forests are cleared to make way for oil palm plantations [25] and developing land for other uses [29]. The severity of the forest fires could be influenced by changing climate conditions [20]. The use of fire for land clearing activities to make way for the expansion of large-scale oil palm plantations is one of the reasons why forest fires keep occurring [11].

4.1 Effect of Haze on Health

Haze in Malaysia usually occurs from January to February and June to August every year, in the dry season [10]. Due to Johor being nearest to Indonesia, Johor is one of the cities that experiences hazes most frequently and severely when compared to other places in Malaysia. In multiple instances, the Air Pollution Index (API) reading in Johor has exceeded the 300 mark, which indicates ‘hazardous’ conditions. One of the most severe cases occurred in 2015, which was comparable to the historic air pollution event in 1997.

The API values and PM_{10} concentrations have been plotted with haze-related morbidity cases for Pasir Gudang and Larkin from 2014 to 2016 as shown in Figure 2. The findings showed that in 2015, the morbidity cases were higher in Pasir Gudang. At that time, Pasir Gudang had the worst readings of haze pollution concentrations, where the status of the API readings surpassed the ‘good conditions’ level in September 2015. Such haze episodes that lead to API readings above unhealthy levels disrupt daily life and activities in Malaysia since outdoor activities will be limited. Some of the effects of hazes is the need to close down schools and declare a state of emergency in regions that are severely affected.

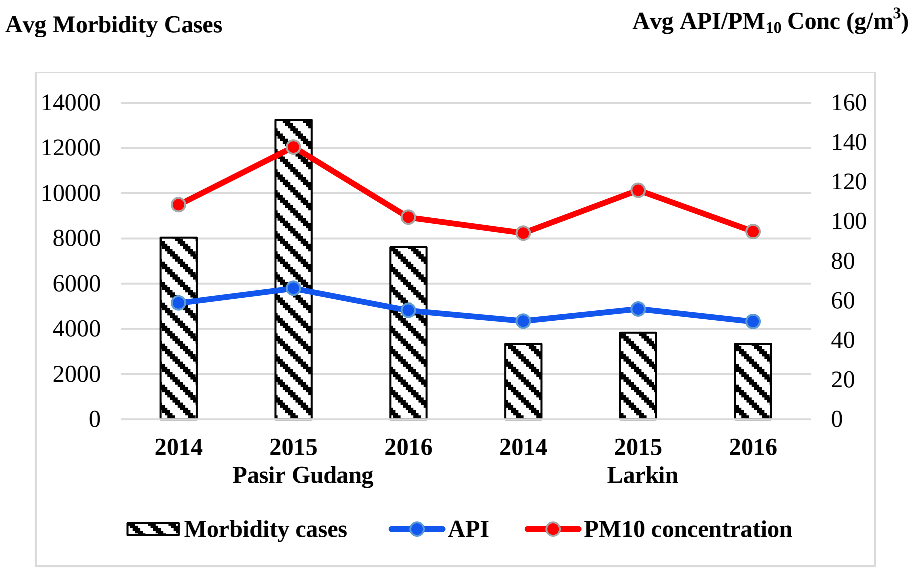

Figure 2 Trend of morbidity cases for Pasir Gudang and Larkin in the years 2014 to 2016.

Fine particulate matter released in the air during transboundary haze can have a severe impact on human health. Particles as small as one micrometer can easily infiltrate indoor air, making exposure unavoidable even for people who remain inside [30]. Smaller particles are more hazardous because they remain longer in the atmosphere and also penetrate more deeply into the lungs. Epidemiological evidence from acute and chronic exposure to PM in ambient air has been linked to a number of different health outcomes, ranging from modest transient changes in the respiratory tract and impaired pulmonary function, through increased risk of symptoms requiring emergency room or hospital treatment, to increased risk of death from cardiovascular and respiratory diseases or lung cancer.

The effects of long-term PM exposure on mortality seem to be attributable to $PM_{2.5}$ rather than to coarser particles. The latter, with a diameter of 2.5-10 µm ($PM_{2.5\text{-}10}$), may have more visible impact on respiratory morbidity [31]. The short-term effect of exposure to high levels of air pollution such as transboundary haze can lead to acute conditions, such as respiratory infections or exacerbation of chronic respiratory illnesses, such as asthma and chronic obstructive airway diseases. Chronic long-term effects of this kind of exposure have not been well studied or established, so more needs to be done in this area [32]. The air pollutants during any haze episode may contain hundreds of chemicals and numerous other elements such as toxic metals that can significantly affect human health.

Evidence of the effect of $PM_{2.5}$ on all-cause, cardiopulmonary and lung cancer mortality has been found. Firstly, with an increase of 10µg/m3 at $PM_{2.5}$, the risk increased to 4, 6 and 8% for all causes, cardiopulmonary and lung cancer mortality respectively. Besides that, long-term exposure to $PM_{2.5}$ and sulphur oxide related to air pollution is a critical factor in cardiopulmonary and lung cancer mortality [33]. It has been proven that $PM_{2.5}$ has a direct correlation with upper respiratory tract infections, as during haze periods patients seek treatment because their symptoms increased [32]. It was deduced that air pollution is largely influenced by meteorological factors, such as temperature, humidity and wind.

The data on the monthly number of outpatients with upper respiratory tract infections (URTI) for Pasir Gudang Health Clinic were plotted along with the PM_{10} concentrations and API levels from the year 2015, as shown in Figure 3.

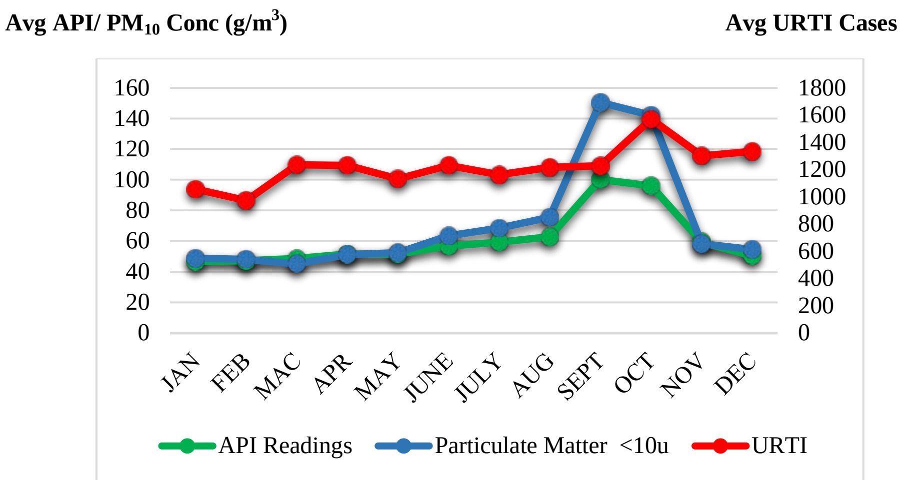

Figure 3 Trend of monthly outpatient rates for Pasir Gudang in year 2015.

In this figure, more insight can be gained into the difference in the number of outpatients between normal and hazy months (September and October). During September 2015, the API readings were at 'unhealthy' levels and this was well represented by a clear incremental change during the haze event relative to normal months. However, when haze episodes occur, the Department of Environment (DOE) issues a ban against any form of open fire burning, especially in Selangor, Malacca and Johor, to prevent further worsening of haze. Those caught making open fires can be fined up to RM 500,000 or a maximum imprisonment up to 5 years, both based on Section 29AA(2) of the Environmental Quality (Amendment) Act 2001. Besides that, DOE advises the public to follow the guidelines and to stay indoors and seek medical attention if feeling unwell. In recent years, especially following the severe case of haze in 2013, ASEAN countries, especially Singapore and Malaysia, have pledged to aid Indonesia in controlling forest fires by carrying out water bombing and cloud seeding. This will help mitigate the effect of haze on neighboring countries.

5 Conclusion

In conclusion, the number of URTI cases was directly proportional to the PM concentration and API values in Johor in the years 2014 and 2015. The findings from this study revealed that $PM_{2.5}$ – the most common particle – is able to initiate detrimental health effects compared to other inhalable particles due to its size, larger area, and stronger activity, making it more likely to carry harmful substances.

Future development needs to recognize that the quality of the environment and the wellbeing of the population should not be subordinated to the objectives of economic development. Governments should apply continuous efforts to control air pollution, especially extreme events like haze, while ensuring the public benefits from economic growth and achieving national promises of good health. After all, haze pollution respects no boundaries and the impacts of health effects touch all populations, in urban regions as well as rural areas. Therefore, health education on limiting outdoor activities and the use of personal protective devices during haze should be provided in all areas to the population.

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