Scientific Report on the Haze Event in Peninsular Malaysia in August 2005

Part II : Physical and Social Aspects

EARTH OBSERVATION CENTRE
UNIVERSITI KEBANGSAAN MALAYSIA

DEPARTMENT OF ENVIRONMENT
MINISTRY OF NATURAL RESOURCE AND ENVIRONMENT MALAYSIA

Scientific Report on the Haze Event in Peninsular Malaysia in August 2005.

Part II: Physical and Social Aspects

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Abbreviation

ADB	- Asian Development Bank
Al	- Aluminium
API	- Air Pollutant Index
APMI	- ASEAN Peatland Management Initiative
ASEAN	- Association of Southeast Asian Nations
ASMC	- ASEAN Specialised Meteorological Centre
ATH	- Agreement on Transboundary Haze
ATHP	- Agreement on Transboundary Haze Pollution
Ba	- Barium
BAPPENAS	- *Badan Perencanaan Pembangunan Nasional*, Indonesia
Br	- Bromin
BSB	- Bandar Sri Begawan
C	- Carbon
Ca	- Calcium
CH_2O	- Formaldehyde
CH_4	- Methane
Cl	- Chlorine
CO	- Carbon monoxide
CO_2	- Carbon dioxide
CRM	- Certified Reference Materials
Cu	- Cuprum
DOE	- Department of Environment
Dy	- Dysprosium
EDX	- Energy Dispersive x-Ray
EEPSEA	- Economy and Environmental Program for South East Asia
EMS	- Environmental Management Society of Malaysia
EPG	- Eminent Persons Group
Eu	- Europium
Fe	- Ferum
FE	- Friends of the Earth
Ga	- Gallium
GIS	- Geographical Information System

H - Hydrogen
H_2 - Hydrogen (gas)
H_2O - Hydro/ water
H_2SO_4 - Sulfuric Acid
HO_2 - Hydroperoxy radical
HTTF - Haze Technical Task Force
I - Iodine
IDW - Inverse Distance Weighted
INC - Intergovernmental Committee
ISO - International Organization for Standard
ITA - Investment Tax Allowance
K - Potassium
MAS - Malaysia Airlines
Mg - Magnesium
MMS - Malaysian Meteorological Services
Mn - Manganese
MSC - Ministerial Steering Committee
N - Nitrogen
N_2 - Nitrogen (gas)
N_2O - Nitrous oxide
Na - Sodium
NGOs - Non Governmental Organizations
NH_3 - Ammonia
NO - Nitrogen oxide
NO_2 - Nitrogen dioxide
NO_X - Oxide of nitrogen
O - Oxygen
O_2 - Oxygen (gas)
O_3 - Ozone
OH - Hydroxide
PAH - Polycyclic Aromatic Hydrocarbon
PAH_S - Polynuclear Aromatic Hydrocarbons
Pb - Lead
PM - Particulate Matters
RHAP - Regional Haze Action Plan
RMAF - Royal Malaysian Airforce

S	- Sulphur
SE	- Southeast
SEM	- Scanning Electron Microscopy
Si	- Silicon
Sm	- Samarium
SO_2	- Sulphur dioxide
Sr	- Strontium
Ti	- Titanium
TPM	- Total Particular matter
TSP	- Total Suspended Particulate
UKM	- Universiti Kebangsaan Malaysia
UNRISD	- United Nations Research Institute for Social Development
URI	- Upper Respiratory Infections
URTI	- Upper Respiratory Tract Infections
V	- Vanadium
WSOC	- Water Soluble Organic Compounds
WWF	- World Wildlife Fund
XRF	- X-ray Fluorescence Analysis
Zn	- Zink

FOREWORD

The August 2005 haze episode that affected the country and southern part of the ASEAN region had been more severe compared to the transboundary haze pollution episode experienced in 1997-1998. The haze episode was much more severe in terms of the total area affected, its impact, duration and intensity. This was due to, among others, the extended drier than normal weather conditions in many areas in the southern part of the region.

Following the incidence, the Department and Earth Observation Centre (EOC) of Universiti Kebangsaan Malaysia took an initiative to document scientifically the August 2005 haze episode. The report focuses on the physical and social aspects of the haze phenomenon.

Finally, I would like to express my sincere appreciation to the team for the excellent work done. It is hoped that this report will serve as a useful reference for relevant stakeholders including the Malaysian public to better understand the haze phenomenon.

DATO' HAJAH ROSNANI IBARAHIM
Director-General
Department of Environment, Malaysia

Preface

This report includes the research on the current understanding of the physical and social aspects of the severe haze that impacted Peninsular Malaysia in August 2005. The need for the second report arose from the culmination of the research efforts of the contributors from Universiti Kebangsaan Malaysia that includes the many different aspects of the haze such as the policy implications, chemical composition of the haze, health impacts, statistical analysis on air quality data, spatial distribution of the haze, and socio-economy issues particularly in the Klang Valley.

The idea for the documentation of this report was mooted by Prof. Dr. Sharifah Mastura Syed Abdullah, the former Head of the Earth Observation Centre, Universiti Kebangsaan Malaysia and the present Dean of the Faculty of Social Sciences and Humanities, UKM. We are grateful for the contribution of Prof. Emeritus Dato' Dr. Sham Sani, and the other contributors listed in this report, without which this report would not be assembled.

This second report titled 'Scientific Report of the Haze Event in Peninsular Malaysia during August 2005, Part II: Physical and Social Aspects', commissioned by the Department of Environment, Ministry of Natural Resources and Environment is a step that paves the path to the understanding of the impacts of the transboundary haze due to biomass burning that occurs in our country nearly every year. It is hoped that further research can be explored and expanded so that the information on the impact on the environment and humans can be disseminated for the greater awareness and knowledge to the public.

Valuable contributions were received from colleagues whose suggestions have improved this report. We wish to expressively thank the following individuals for their review of this report:

(i) Prof. Dato' Dr. Abdul Latiff Mohamad from the Faculty of Science and Technology, Universiti Kebangsaan Malaysia

(ii) Dr. Ir. Shamsudin Abd. Latif, the Deputy Director (Development) of the Department of Environment, Ministry of Natural Resources and Environment.

The reviewers were not asked to endorse the reports' contents although they have provided constructive comments and suggestions. Responsibility of the final content of the report rests entirely on the authors and editors.

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August 2007

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CHAPTER 1

Haze in Malaysia: An Overview

Sharifah Mastura Abdullah, Sham Sani and Nor Aziah Jaafar

1.1. Introduction

In many megacities of Asia, the challenge is to manage air pollution which due to increased use of motor vehicles, industries and infrastructural development. In Malaysia, for more than two decades now, we are faced not only with our own air pollution issues due to in the process of economic development but also air quality deterioration in the form of transboundary haze pollution from neighbouring Sumatera and Kalimantan, Indonesia during the dry months of June-September/ October and February-March.

The main cause of this transboundary air pollution, a phenomenon which is referred to locally as the 'haze', is intentional land clearing variously attributed to commercial oil palm and timber plantations, forest fires, illegal logging practices and local smallholders. The haze itself is 'episodic' in nature. It is characterised by high level particulate matter concentrations and other gaseous pollutants. It is a health hazard, disrupts air and sea transport and affects millions of people in Sumatera, Kalimantan, Singapore, Brunei Darussalam and, of course, Malaysia. Conditions can become worse and prolonged when such months with the haze episodes coincide with the occurrence of the well known El Nino.

This report provides an overview of this transboundary haze pollution. It defines the issues, traces the history of the episodic haze occurrences since the late 1980s, and discusses the management response and the challenges both for Malaysia and Indonesia and for all the other affected ASEAN member countries, especially Singapore and Brunei Darussalam.

1.2. The Issue: With Special Reference to the 1997 Haze

The haze phenomenon was first realized in the early 1960s (Sham et al. 1991). Unfortunately, available records were scanty during these early years although the haze even then had become almost a regular feature of our Malaysian environment, notably during the dry months of February to April and June to September/October. Perhaps the haze of September 1982 and April 1983, which coincided with the occurrence of widespread bush fires and agricultural waste burning in Indonesia, was among the first to hit the headline. It attracted a great deal of public attention and created intense debates in the local media. Since then, there has been a number of haze 'episodes' of different magnitudes and intensities in Malaysia with varying socio-economic and health-related consequences.

Perhaps the longest and the worst episode and the one which received the most attention occurred during September to November 1997. It was caused not only by external sources that exacerbated the contribution from internal sources but also coincided with the El Nino, which prolonged the dry season until the middle of the following year, thus setting a conducive environment for the haze formation.

During the September to November 1997 haze episode, Indonesia, Singapore, Brunei Darussalam and Malaysia were severely affected. The main cause of the haze was mainly intentional land-clearing in Sumatera, Indonesia attributed to land clearing by commercial oil palm and timber plantations, government-sponsored transmigration projects, and local smallholders. Internal sources such as open burning and pollutant discharges from motor vehicles were also contributory factors. Azman (1997) argued that in the 1997 haze, only about 20% of the haze composition in Kuala Lumpur was attributed to local pollution largely from motor vehicles and industries; the rest originated from outside the national boundary.

An estimated 70 million people were affected by the haze, with the worst-hit areas being in southern Sumatera and southwestern Borneo. Conservative estimates by the World Wildlife Fund (WWF) put the total amount of burned forest at 6,000,000 acres. The fires were further enhanced by the meteorological conditions prevailing at the time. In the latter case, the southwest monsoon winds bearing pollutants from the forest fires blew across Kalimantan, Sumatera, Singapore, Southern Thailand, Brunei Darussalam and almost all parts of Malaysia. The episode was further exacerbated by the fact that it also coincided with the El Nino phenomenon, which affected Indonesia and most of Southeast Asia and at the same time prolonging the dry season and intensifying forest fire risks.

Samples of air pollution levels, as indicated by the air pollution index (API) taken during the haze period in September and October of 1997 for urban centres in the Klang Valley Malaysia are shown in Table 1.1. The air pollution index (API) is derived based on five pollutants — SO_2, O_3, CO, NO_2 and PM_{10}. For PM_{10} and SO_2, the mean concentration is averaged for an hour after 24 hours exposure. For CO, the one-hour reading is taken after eight hours of exposure and for O_3 and NO_2, the readings are taken after one hour of exposure each. Indices for each of the pollutants are then computed; the highest index recorded is taken as the API reading.

Table 1.1 Percentage frequency of occurrence (days) with specific API categories for urban centres in the Klang Valley during the haze period, September to October 1997

API Category	Kuala Lumpur	Petaling Jaya	Klang	Kajang
Good (0 - 50)	0.0	8.2	4.2	20.0
Moderate (51 - 100)	30.6	34.6	32.0	26.0
Unhealthy (101 - 200)	49.0	49.0	59.6	50.0
Very Unhealthy (201 - 300)	18.4	8.2	4.2	4.2
Hazardous (301 and above)	2.0	0.0	0.0	0.0

[Source: Calculated based on data from DOE]

It is observed that all centres experienced 'Unhealthy' condition for more than 50% of the time; Kuala Lumpur had 69.4%, Petaling Jaya 57.2%, Klang 63.8% and Kajang 54.2%. For 'Very Unhealthy' days Kuala Lumpur had the highest share with 20.4%, Petaling Jaya 8.2%, Klang 4.2% and Kajang 4.0%. Kuala Lumpur also recorded 2.0% of days with 'Hazardous' API readings. Meanwhile, API readings for Kuching indicated four months of moderate to unhealthy conditions. The El Nino which lasted until mid-1998 prolonged the dry season in many parts of Malaysia, Indonesia and other Southeast Asian countries.

The haze from forest fires that ravaged Indonesia and much of Southeast Asia during 1997 cost the region almost USD 1.4 billion. More than 90% of Indonesia's losses were attributable to short-term health costs (WWF, 1999). Costs to Malaysia exceeded USD 300 million, mainly from industrial production losses and lost revenues from a big drop in tourism. Singapore lost more than USD 60 million, mainly from a drop in tourist visits. Indonesia also lost nearly USD 90 million from foregone tourist revenues, airline cancellations and airport shutdowns, while Malaysia and Singapore together suffered almost USD 12 million in health costs (WWF, 1998). The study did not take into account such costs as long-term damage to health and losses directly attributable to fire, which are believed to be considerable, possibly equalling, if not exceeding, those of the haze alone.

1.3. Selected Major Haze Episodes: 1980 - 2006

Since about 1980, there have been several reports of haze episodes affecting Malaysia. The 1997 haze, the worst to hit Malaysia so far, was discussed earlier in the previous section. This section provides a brief description of some selected major haze episodes that had affected Malaysia during the 1980 to 2006 period. A large part of this section is heavily based on newspaper reports and the electronic media.

1.3.1. Haze 1983

One of the earliest reports on the haze episodes was documented in April 1983 (The New Straits Times, 1983a). According to this report, two Malaysia Airlines (MAS) flights between Ipoh and Penang were cancelled on 4th April 1983 due to severe haze. Visibility was down to 1,000 meters. The Meteorological Department said the intense haze prominent in the northern states was mainly caused by suspended dust particles due to the dry spell. The haze was also aggravated by the occurrence of thermal inversion which prevented atmospheric mixing and enhanced the suspension of dust particles in the air.

The hazy conditions with varying severity persisted until the end of April. It was so severe on 20th April that three MAS flights scheduled to depart from Sandakan Airport were cancelled. Visibility was down to 100 m at 8:00 am (The New Straits Times, 1983a).

1.3.2. Haze 1990

The hazy condition which was widely reported in the local media in August 1990 occurred during the period from 15th till 30th August, with the worst haze condition recorded from the 20th till 30th August. Complaints of increased asthma cases, poor visibility and a general feeling of depression were reported in the local papers (The New Straits Times, 1990a; 1990b).

The August haze also caused several transport disruptions. The fighter jet fly-past and parachuting display scheduled for the National Day celebration on 31st August were cancelled and light aircraft banned from flying until further notice. In Port Klang, poor visibility caused at least one ship to run aground and delayed the arrival and departure of 30 vessels. According to reports (The New Strait Times, 1990b), Subang Airport was closed to incoming flights for nearly two hours following the two incidents involving the Royal Malaysian Airforce (RMAF) fighter jets. Several incoming MAS flights during the period were diverted to Penang or Singapore while outgoing flights were delayed.

Based on available records at Petaling Jaya during 1977 to 1989, the mean total suspended particulate (TSP) values for August and September were normally between 80 to 95 μgm^{-3}. However, during the first week of August 1990, TSP levels were consistently above 100 μgm^{-3}. The values were lower in the following week due to scattered rain in Selangor. This break however was shortlived. From 16th August, the TSP levels rapidly increased reaching an unprecedented value of 516 μgm^{-3} over a 12-hour period on 27th August 1990. A more detailed account of the 1990 haze was documented in Sham et al. (1991).

1.3.3. Haze 2005

The haze episode in 2005 which occurred during August to September was the worst since the 1997 haze. It began around 3rd August when almost 600 hotspots detected in Riau and North Sumatera, caused a sudden thick haze in the affected areas. In Sepang and Petaling Jaya on this occasion, ground visibility was as low as 1.0 km, while in Seremban ground visibility was down to 500 m. The hazy condition with varying intensities continued until past mid-September of 2005 (The New Straits Times, 2005c).

On 10th August, eight locations (Ipoh, Sri Manjung, Tanjung Malim, Petaling Jaya, Kuala Lumpur, Kuala Selangor, Nilai and Seremban) experienced 'unhealthy air' with API values ranging between 101 and 200. Visibility in Subang was about 3.0 km in the morning but dropped to 0.8 km by 2 pm, and 100 m by 5 pm. In Petaling Jaya, visibility dropped from 6 to 7 km in the morning to 1.0 km by 5 pm. Ships plying the Straits of Malacca were warned of the reduced visibility to about 1.0 km in the middle and southern parts of the Straits (The New Straits Times, 2005e). By 11th August 2005, two areas in Selangor (Port Klang and Kuala Selangor) were declared as haze emergency zones with API rising above 500. In Port Klang and Kuala Selangor the API readings were 529 and 531 respectively. Many schools were closed as air quality deteriorated. The hazy conditions persisted until well after mid-September of 2005.

1.3.4. Haze 2006

In 2006, Malaysia experienced three short-term slight to moderate haze episodes due to transboundary haze pollution, namely in mid July, mid August and late September to October 2006.

In the July episode, three air monitoring stations located in the west coast of Peninsular Malaysia i.e. Seberang Perai in Penang, Port Klang in Selangor and Sri Manjung in Perak recorded unhealthy status for the period of 17, 18 and 19 July 2006. In mid August 2006, air quality monitoring stations in Sarawak i.e. Kuching, Sibu, Sarikei, Samarahan, Sri Aman, Petra Jaya and Bintulu recorded unhealthy levels.

The haze was more intense in late September and early October 2006. The worst hit was Sri Aman in Sarawak, which registered the highest Air Pollutant Index (API) of 221 (very unhealthy level) on 6 October 2006. Hazy condition was also experienced in Peninsular Malaysia, where twenty stations recorded unhealthy air quality levels on 7 October 2006.

To summarise, it is noted that generally the duration of a particular haze episode varies according to prevailing weather conditions or whether the haze coincides with the occurrence of El Nino. The latter has the effect of prolonging the dry weather, resulting in the extended duration of the haze episode such as in 1997. The magnitude of the haze, on the other hand, depends on the intensity of the internal and external sources of pollution. In many cases, external sources from Kalimantan and Sumatera determine the severity of the haze. In this instance, the southwest monsoon, which generally blows over Kalimantan and Sumatera during May to September/October transports the pollutants from forest and peat fires and burning of agro-wastes across to Singapore, Brunei

Darussalam and Sabah, Sarawak and Peninsular Malaysia. It is the transboundary nature of the pollution that has now become the concern of not only Indonesia but also her affected neighbours.

1.4. Management Response

For many years, and especially since the early 1990s, ASEAN member nations have worked together on regional plans to reduce open burning and control air pollution. However, the 1997 haze episode provided ASEAN with a sense of increased urgency to address the issue.

Since the severe land and forest fires and transboundary haze pollution in 1997, ASEAN member nations have taken many initiatives including actions on the ground to address land and forest fires and the resulting transboundary haze pollution. These initiatives include:

1) the implementation of the Regional Haze Action Plan (RHAP);
2) the ASEAN Agreement on Transboundary Haze Pollution;
3) the ASEAN Peatland Management Initiative (APMI);
4) the zero-burning and controlled-burning guidelines; and
5) the activation of the Panel of ASEAN Experts on Fire and Haze Assessment and Coordination.

1.4.1. The Regional Haze Action Plan (RHAP)

In June 1995, ASEAN Environment Ministers had agreed on an ASEAN Cooperation Plan to address haze pollution. The Cooperation Plan contains broad policies and strategies to deal with transboundary haze pollution. Three main objectives were identified as follows:

a) to prevent land and forest fires through better management policies and enforcement;
b) to establish operational mechanism to monitor land and forest fires; and
c) to strengthen regional land and forest fire-fighting capability and the mitigating measures.

In order to meet these objectives, three strategies were proposed and agreed on, i.e. Preventive Measures, Regional Monitoring Mechanisms, and Fire Fighting Capability.

1.4.1.1. Preventive Measures

Under the RHAP strategy, ASEAN countries fully recognize the need to strengthen national policies and strategies to prevent land and forest fires. It also recognizes that while some member countries have already developed their policies and strategies, others are still in the process of improving them based on their own particular development needs, priorities and constraints. Nevertheless, ASEAN countries generally agreed to develop their National Plans taking cognizance of the need to address land and forest fires in their policies and strategies. The following common elements were agreed upon and included in the National Plans of each member country:

a) Policies to curb activities that may lead to land and forest fires, and control emission from mobile and stationary sources, including the prohibition of open burning and the strict control of land clearing practices during the dry period.
b) Strategies to curb activities that may lead to land and forest fires, and control emission from mobile and stationary sources, including formulation of air quality management legislation to prohibit open burning; strict

enforcement of laws and legislation; implementation of air quality monitoring and reporting regimes. The setting up of inventory of sources of emission, both mobile and stationary; establishment of a national task force committee to develop strategies and response plans to deal with fires and smoke haze is also part of the strategy, including utilisation of information technology to provide haze-related information to relevant agencies to prevent and control spread of fire, and to enhance public awareness on the haze situation.

c) Guidelines and support services to discourage activities that can lead to land and forest fires;
d) Operating procedures for the early mobilisation of resources to prevent the spread of fires;
e) Development of markets for the economic recovery and utilization of biomass and appropriate methods for the disposal of agriculture wastes.

1.4.1.2. Regional Monitoring Mechanisms

Under this strategy, the RHAP will strengthen the mechanism to provide an alert of the first outbreak of land and forest fires, an assessment of meteorological conditions, a prediction and systematic tracking of the spread of fires and haze, and the necessary data to support enforcement action. The ASEAN ASMC located in Singapore has been streamlined and strengthened to serve as a regional information centre for compiling, analysing and disseminating information derived from satellite imagery and meteorological data necessary to detect and monitor land and forest fires, and the occurrence of smoke haze.

It also includes the region's early warning system to provide an alert of the first outbreak of land and forest fires, an assessment of meteorological conditions, a prediction of the spread of fires and haze, and the necessary data to support enforcement action.

An intranet among the relevant ASEAN meteorological service and environment agencies was also established to improve communication and enhance the effectiveness of existing early warning and monitoring mechanisms. Since late 2003, the coverage of ASMC has been extended to the whole region.

1.4.1.3. Fire Fighting Capabilities

National and regional land and forest fire-fighting capabilities will be strengthened through the following measures:

a) The inventory of land and forest fire-fighting capabilities of each country and identification of resources that can be made available for regional fire-fighting efforts (completed by March 1998);
b) A programme to strengthen the fire-fighting capabilities of individual countries and the region, and a compilation list of equipment and technical expertise needed at the regional level to tackle land and forest fires (completed by March 1998);
c) The sources of technical assistance for (b) within and outside ASEAN, and, if required, an assistance programme by each donor country. Technical assistance may include forest fire-fighting equipment, aircraft such as water bombers, high-tech equipment and experts to command post operations (completed by March 1998);
d) An operating procedure to activate the development of the fire-fighting resources in each country for regional

fire-fighting operations (established by June 1998); and

e) A mechanism in each country to provide, in the event of an outbreak of land or forest fires, regular updates to the Haze Technical Task Force (HTTF) on progress made in the efforts to fight the fires. The updates would include the number of hotspots and their locations, analysis of fire types, problems encountered, adequacy of deployed resources, and effectiveness of enforcement and ground operations (established by June 1998);

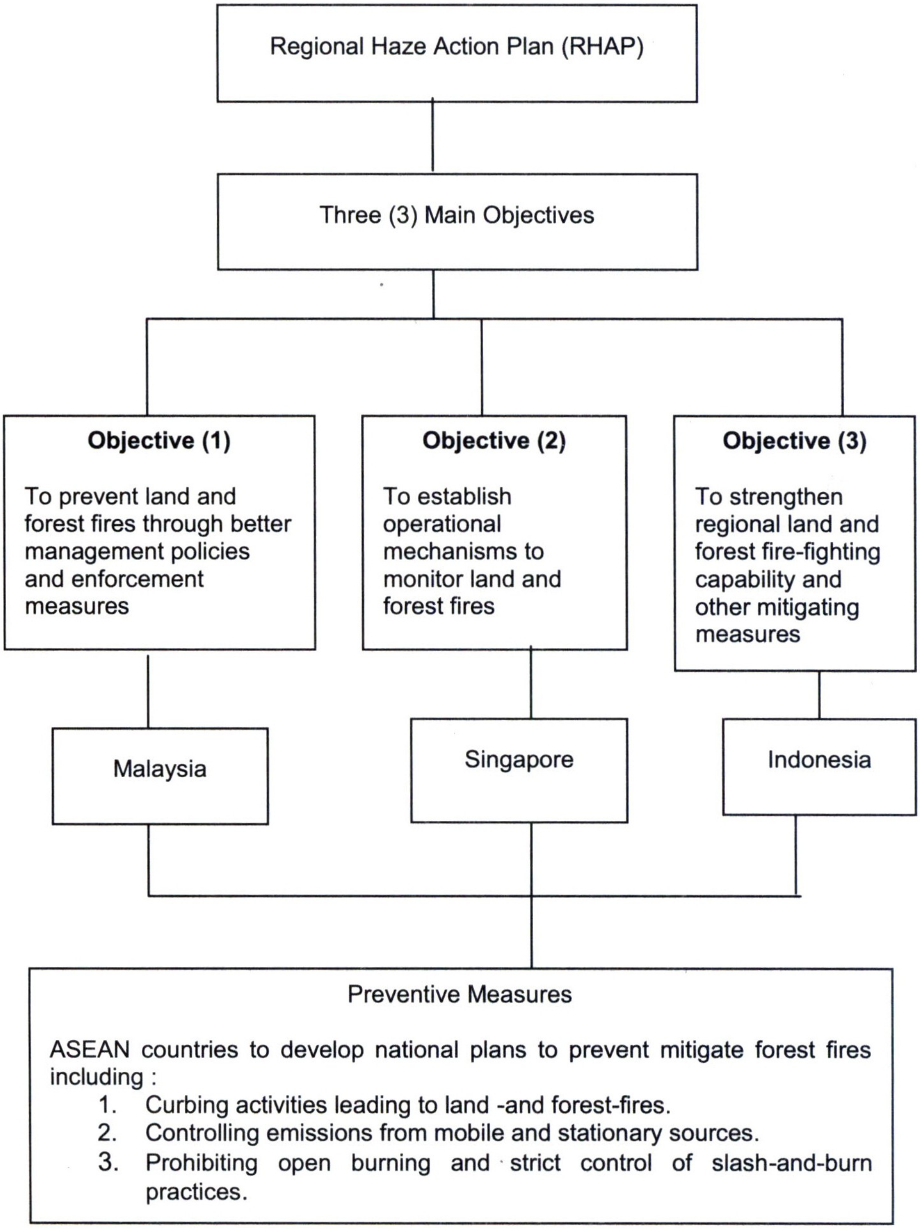
The RHAP was adopted at the ASEAN Ministerial Meeting on Haze in December 1997. Three ASEAN member countries (Indonesia, Singapore and Malaysia) agreed in December 1997 to collectively take measures to prevent future forest and peat fires and haze. According to the Plan, Malaysia takes the lead in prevention, Singapore in monitoring and Indonesia in fire-fighting (Figure 1.1).

1.4.2. The Agreement on Transboundary Haze Pollution 2002

In 1999, ASEAN took a step further by adopting the policy on zero-burning. In October 2000, the Environment Ministers agreed to forge ahead with the formulation of an ASEAN Agreement on Transboundary Haze Pollution (ATHP) and an intergovernmental committee (INC) was formed to draft the Agreement. The Agreement aims to further operationalise and institutionalise existing arrangements in addressing transboundary haze pollution. It calls for parties of the Agreement to undertake:

a) Legislative and administrative measures to prevent and control activities related to land and forest fires that may result in transboundary haze pollution; and
b) National and joint actions to intensify regional and international cooperation to address transboundary haze

pollution.



Objective (1)

To prevent land and forest fires through better management policies and enforcement measures

Objective (2)

To establish operational mechanisms to monitor land and forest fires

Objective (3)

To strengthen regional land and forest fire-fighting capability and other mitigating measures

Preventive Measures

ASEAN countries to develop national plans to prevent mitigate forest fires including :

1. Curbing activities leading to land -and forest-fires.
2. Controlling emissions from mobile and stationary sources.
3. Prohibiting open burning and strict control of slash-and-burn practices.

Figure 1.1 ASEAN regional haze action plan

The Agreement also seeks to formalise mechanisms for communication and sharing of information on land forest fires and the resulting transboundary haze pollution, through the establishment of an ASEAN Centre for Transboundary Haze Pollution Control.

The ASEAN ATHP was signed by ten member countries of ASEAN on 10 June 2002 in Kuala Lumpur during the World Conference and Exhibition on Land and Forest Fire Hazards. The Agreement is one of the first such regional arrangements in the world that binds a group of contiguous states to tackle transboundary haze pollution resulting from land and forest fires.

The ASEAN ATHP contains a preamble and six major parts with a total of 32 Articles as follows:

Part I : General Provisions (4 Articles: Articles 1 to 4)
Part II : Monitoring, Assessment, Prevention and Response (11 Articles: Articles 5 to 15)
Part III : Technical Cooperation and Scientific Research (2 Articles: Articles 16 to 17)
Part IV : Institutional Arrangements (3 Articles: Articles 18 to 20)
Part V : Procedures (7 Articles: Articles 21 to 27)
Part VI : Final Clauses (5 Articles: Articles 28 to 32)

Basically, the objective of the Agreement is to 'prevent and monitor transboundary haze pollution as a result of land and/or forest fires which should be mitigated, through concerted national efforts and intensified regional and international cooperation'. It should be 'pursued in the overall context of sustainable development and in accordance with the provision of this Agreement' (Article 2).

The Agreement itself focuses on matters regarding monitoring, assessment, and prevention of transboundary haze and the kind of technical cooperation, R&D and institutional arrangement required in order to meet the objectives of the Agreement.

Some of the basic infrastructures have already been put in place, largely in response to the Regional Haze Action Plan (RHAP) which was agreed to earlier by ASEAN. Some of these include the establishment of the ASEAN Specialised Meteorological Centre (ASMC) and the ASEAN Haze Technical Task Force (HTTF).

The ASEAN Ministers responsible for environment agreed to work towards ratifying the ASEAN A-THP as soon as possible to ensure that regional efforts are further enhanced through the legal mechanisms provided for in the Agreement. The Agreement requires at least six ratifications to enter into force. The ASEAN ATHP finally came into force on the 25 November 2003 following the deposit of the sixth instrument of ratification by the Government of Thailand with the Secretary General of ASEAN on 26 September 2003. The Agreement provides for its entry into force 60 days after the deposit of the sixth instrument of ratification. Brunei Darussalam, Malaysia, Myanmar, Singapore, and Vietnam had earlier deposited their instrument of ratification/ approval. It is interesting to note that at the time of writing, Indonesia has still not ratified the Agreement on Transboundary Haze Pollution 2002.

Following the haze episode in October 2006, a Sub-regional Ministerial Meeting on Transboundary Haze Pollution was held in Pekanbaru on 13 October 2006. The Meeting was attended by the Ministers and other high ranking officials responsible for the environment from Brunei Darussalam, Indonesia, Malaysia, Singapore and Thailand. Nine province Governors from Indonesia, ten regents of the Riau Province as well as representatives of

ASEAN Secretariat were also present in the Meeting as observers.

According to the joint press statement issued by the ASEAN Secretariat, the Meeting discussed urgent measures to jointly tackle the common problems caused by transboundary haze pollution. The Meeting assessed the sub-regional efforts to manage the problems caused by transboundary haze pollution and noted the efforts taken by countries in the region while acknowledging that the haze problem had not been adequately addressed. The Meeting appreciated the Indonesian efforts to tackle land and forest fires that resulted in transboundary haze pollution and was committed to support Indonesia in its endeavour.

The Meeting seriously discussed many important topics including an update of regional transboundary haze situation and weather forecast, progress update by Indonesia of its measures adopted to prevent and mitigate land and forest fires in Sumatera and Kalimantan. At the same time, the Meeting highly appreciated Malaysia's initiative in the funding and operationalisation of the ASEAN transboundary haze pollution control. The Meeting also respectfully urged Indonesia to urgently finalise the ratification of the ASEAN Agreement on Transboundary Haze Pollution in accordance with its national law.

The Meeting further agreed to set up a Ministerial Steering Committee (MSC) to oversee the implementation of short and long-term plans to effectively tackle the haze problem. The Committee comprises the Environment Ministers from Brunei Darussalam, Indonesia, Malaysia, Singapore and Thailand.

1.4.3 Malaysia's Response to National Policies in ASEAN Countries.

1.4.3.1 Legislation

In Malaysia, efforts to control sources of air pollution, open burning and haze started in the 1970s when the Motor Vehicle (Control of Smoke and Gas Emissions) Rules 1977 (made under the Road Traffic Ordinance, 1954) and the Clean Air Regulations 1978 were enacted. In addition, the Control of Lead Concentrations in Motor Gasoline Regulations 1985 also contributed to air pollution control management.

Under the Motor Vehicle Rules 1977, it is an offence for motor vehicles to emit dark smoke in excess of 50 Hartridge units. This is especially relevant with respect to diesel-powered vehicles such as buses, lorries and taxis which operate in concentrated numbers in urban centres. Standards for gas emissions for petrol-driven vehicles are also being enforced by the Department of Environment (DOE).

The Environmental Quality (Clean Air) Regulations 1978 provide for detailed specifications on waste burning, dark smoke emissions by factory chimneys, and the emission of air impurities generally. Under the Clean Air Regulations, certain potentially polluting industries are not allowed to be anywhere within 1000 m of a residential area without prior written approval from the Director-General of DOE. It is also stipulated that (1) burning of industrial and trade wastes must be done in an approved incinerator; (2) the installation, resiting and alteration of fuel burning equipment should first obtain prior written approval of the Director-General of DOE, and (3) open burning of industrial wastes or refuse is prohibited. With effect from October 1978 it was also mandatory for new industrial and trade premises to ensure that smoke emissions are not darker than shade no.1 on the Ringelmann Chart for burning equipment using liquid fuel, and shade no.2 for those using solid fuel. For trade premises which were in operation before October 1978, the smoke emissions should not be darker than shade no.2 of the Ringelmann Chart with effect from March 1979.

The Environmental Quality (Control of Lead Concentration in Motor Gasoline) Regulations 1985 require that lead content in motor gasoline be reduced to 0.15 gm/liter on and after 1 January 1990. Indeed, the response from motor gasoline companies was so good that now virtually all patrol pumps are selling unleaded petrol.

Controls of air pollution through legislation such as those described above are mostly short-term and remedial in nature. As a complementary strategy to minimise pollution, *Guidelines for the Siting and Zoning of Industries* (DOE, 1976) were introduced. The main feature of these Guidelines is the incorporation of environmental component as an integral element in the medium-term development planning process with a view of bringing about an ecologically balanced relationship between development and environment. Under this guideline, the use of 'buffer zones' is encouraged between industries and residential areas or even between different industrial areas. The guidelines also allow for light industries to be located near housing or in built-up areas. However, as the potential for pollution increases, the distance from the residential areas needs to be increased accordingly from 500 to 1000 meters for general industries to 1500 to 3000 meters for 'special industries'.

Apart from *Guidelines for the Siting and Zoning of Industries* (DOE, 1976), there are other guidelines which directly attempt to control air pollution. These include *EIA Guidelines for Municipal Solid Wastes and Sewage Treatment and Disposal Projects* (DOE, 1995a) and *EIA Guidelines for Mines and Quarries* (DOE, 1995b).

During the haze period, all legislation pertaining to air pollution including open burning and earthworks was enforced more strictly. Indeed, many of the litigations and prosecutions of non-compliance took place during the haze period (The New Straits Times, 1997). Several construction activities were advised to be put on hold and as a precaution, several schools in Sarawak were closed when the API were exceedingly high, in excess of 500.

More recently in the midst of the 1997 haze, the EQA 1974 was amended to reemphasise Malaysia's concern regarding open burning. The amendment, EQA (Amendment) 1998, was officially passed by Parliament on May 13, 1998 and accepted by the Senate on 4th June 1998. It was gazetted as Act A 1030 on 1st July, 1998 following the Royal sanction on 25 June, 1998. The amendment must have been one of the fastest amendments to be approved by Parliament, the Senate, and the Yang Dipertuan Agong signifying its urgency.

In the Amendment, two new provisions (Section 29A and 29B) were introduced. Section 29A prohibits any form of 'open burning' with a penalty of RM 500,000 or five years jail or both for non-compliance. Section 29B states that the owner(s) or the occupier(s) of a premise will be held responsible for open burning occurring in that premise.

1.4.3.2. Public Awareness and Support

What has been described so far are the management responses and initiatives at the regional, international and national levels. However, while legislation and institutions in the administration of policies and programmes of environmental management are important, public support is equally crucial in order to ensure the success of such programmes. The bottom line is no conservation programme, however good it may be designed, can be completely successful without public support, which can only come from well informed citizens who are aware and fully committed. This must include all sections of the communities, from administrators, politicians and the private sector right down to the ordinary man in the street and school children. At both the regional, national and local levels, efforts to educate the public and disseminate environmental information must be intensified. Since environmental education is basically aimed at community actions, efforts to reach different target groups must be varied and involve not only governmental institutions but also a wide variety of professional groups, the private sector and non-governmental organisations (NGOs).

The role of NGOs in environmental education has long been accepted. Their activities are aimed at both effecting changes and shaping attitudes, and so, directly or indirectly, they are involved in environmental education. Of great significance is the role of the NGOs in providing a mechanism for feedback to the government and its regulatory agencies and negative side-effects of programme implementation. In many respects, they perform a watch-dog function on behalf of the public on the use and abuse of natural resources, conservation, professional practices and other activities that adversely impinge upon the environment. The government, for its part, should be willing to listen to alternative views without prejudice. In some cases, this can be difficult as environment and development are closely linked, and environmental NGOs may easily be dismissed as being anti-development and trouble makers.

Apart from creating awareness, enhancing commitment to conservation through environmental education, and hence public support for environmental programmes, economic instrument as management tools in environmental conservation should also be applied whenever the situation warrants it, although these may not be too popular with certain quarters. Experiences have shown that preventive measures tend to become more effective when they are packaged in terms of dollars and cents. Indeed, several of these economic instruments are already in place, mainly in the form of economic incentives, and should be expanded further if there are objections from certain groups (Table 1.2). In this respect, the gradual acceptance of ISO 14000 by Malaysia is a move in the right direction. The ISO 14000 is an effort by the International Organization for Standard (ISO) to 'standardise' environmental management system internationally covering environmental management systems, environmental auditing and related environmental investigations, environmental labeling, environmental performance evaluation and life cycle assessment.

A system of this kind enables an organisation to establish, and assess the effectiveness of procedures to set an environmental policy and objectives, achieve conformance with them, and demonstrate such performance to others. For many years, this initiative has been dominated by developed countries like the U.S., Canada, the U.K., France, Norway, Australia, Germany and the Netherlands. Indeed, some influential business houses have already begun or are planning to apply specific environmental standards to their trading partners. Once ISO 14000 is in place, there is every reason to believe that it will become commercial standard for environmental management. An organisation which is unable or unwilling to play the game and meet such standard will lose trading partners and limit its strategic alliance capability. Malaysia is fully aware of ISO 14000, its advantages, consequences and possible trade implications both at an organisational level and as a trading nation operating in highly competitive international environment. A number of trade organisations in Malaysia are already implementing the ISO/DIS 14001 Environmental Management Systems - Specification with Guidance for use on a voluntary basis.

Table 1.2 Examples of incentives for the protection and conservation of the environment

1. Pioneer status investment tax allowance (ITA) for companies undertaking a forest plantation project.
2. Pioneer status ITA for companies undertaking reprocessing of certain waste such as agricultural and chemical wastes.
3. Pioneer status ITA for companies storing, treating and disposing of dangerous toxic wastes.
4. Special capital allowance for companies providing facilities for storing, treating and disposing dangerous toxic waste produced by its own factory.
5. Exemption of import duty, sales tax and excise duty on machinery equipment to manufacturing companies for the control of population.
6. Exemption of import duty, sales tax and excise duty on machinery equipment and raw material required for undertaking activity listed in (2) and (4).
7. A price differential of 3 cents/liter between leaded and unleaded petrol through a price reduction on unleaded petrol effective from January 1, 1994.

8. Import and sales tax exemption for catalytic converters.
9. Import duty for new diesel powered passenger cars reduced to 120%. Motor vehicle license fees on road tax reduced for new generation diesel-powered motor vehicles that half of the existing rate.
10. Donations to an improved organisation established exclusively for the protection and conservation of the environment are allowed as deductions in the computation of income tax purposes.
11. A forest plantation project is recognised as a strategic project of national interest and is eligible for the special incentives:
    (a) Pioneer status with 100% tax exemption for 10 years; or
    (b) Investment tax allowance at the rate of 100% for 5 years,

(Source: The 1994 and 1995 Budget Speeches by the Minister of Finance Malaysia)

An equally important point to remind ourselves of is the need to realise that environmental management and conservation are a shared responsibility. While the environment is a common concern, its intensity and extent of usage vary from one group of the community to another. Some use it more than others and, in the process, destroy it; some benefit excessively from it. In view of the different contributions to environmental degradation and benefits derived from environmental resources, the 'shared responsibility' should somehow be differentiated, in line with the spirit embodied in Principle 7 of the Rio Declaration in 1992. This is important in that it lays the basis for the equitable sharing of responsibilities. While every member of the community is expected to assist, the more endowed section of the community, especially the corporate sector will need to shoulder greater responsibility and contribute more substantially to environmental cause.

1.5. The Challenges

From the foregoing discussion it will be observed that ASEAN nations have already formulated an overall response mechanism for the region. The Haze Action Plan and the Agreement on Transboundary Haze for example, are already in place and they are continually being refined, perfected and gradually implemented. This system will provide the means for early fire detection through satellite monitoring, aerial and ground surveillance weather forecasting, and surface-based atmospheric modelling. In addition, its fire fighting forces will be coordinated at the national level with fire fighting teams from other nations that can come to the assistance of local fire fighters. This network in turn, will be linked through communication channels via the internet, a regional intranet emergency response service, telephone and telefax capabilities, and radio channels dedicated to emergency response communications. Regional plans are also being developed, refined and perfected to increase the capacity for enforcement of regulations, promote public education and awareness, provide regional air quality monitoring capabilities, commission studies to assess health and socioeconomic impacts, design and implement a fire danger rating system, and enforce effective land use planning to promote sustainable development on a regional basis.

Transboundary haze pollution is a major regional problem. It cannot be contained by any single member nation of ASEAN without the cooperation from other neighbouring nations. Indeed, no government, however committed, is able to control effectively many such environmental problems alone without the support and cooperation from the public. Support from the latter, however, can only come from a public who is aware of the problem and is sufficiently committed to contribute in the control, mitigation and management of the problem. It is in this regard that the Secretary-

General of ASEAN emphasised the point that it was all very well for ASEAN to have agreements and action plans to tackle the haze problem, but their implementation needed the support of civil society groups (Jakarta Post, 2002).

One immediate challenge which is shared by almost all ASEAN member nations concerns the effective enforcement of the existing environmental and environment-related legislation. Many observers feel that while some ASEAN nations have some of the best sets of environmental legislation the effective implementation of such legislation is far from impressive. A good piece of legislation is only effective if it can be enforced such that it meets the objectives for which it was enacted in the first place. This requires support facilities. It requires manpower and resources, the cooperation of the various government agencies and the support of the state and local governments. Likewise, the support from the public is equally crucial.

No legislation and no conservation programme, however good it may be designed, could be successful without public support. This could only come from well-informed citizens who are aware of their right to quality environment. This includes all sections of the community from politicians, administrators and the private sector right down to school children and the ordinary public. There is thus a need for a concerted effort to educate the public and disseminate environmental information involving government institutions, the media, the private sector and the NGOs to reach the different target groups.

1.6. Conclusion

This section of the report has been concerned with transboundary haze pollution in Southeast Asia. It provides a review of the haze problem by first defining the issue followed by a brief description of some of the haze episodes since about the 1980s. It then discusses the management response and the challenges both for Indonesia, the affected member countries of ASEAN (Malaysia, Singapore, and Brunei Darussalam) and ASEAN as a region. This report argues that transboundary haze is a multi-faceted problem affecting several ASEAN member countries. A holistic approach is needed to alleviate the problem, including the role of civil societies and the support of the NGOs. Although the RHAP and the ATH have been put in place, the effectiveness of such efforts will depend not only on the full commitment of each of the members but also their capacity to meet their respective obligations as stipulated in the Agreement and Regional Plan.

CHAPTER 2

Chemistry of Haze

Abdul Amir H. Khadum

2.1. Introduction

The history of forest fires and their effects have been well documented in numerous studies and reports (Radojevic, 1998; Radojevic and Tan, 2000; Heil and Goldammer, 2001; Soleiman et al., 2003; Radojevic, 2003a, b; Jones, 2006). Southeast (SE) Asia has experienced several smoke and haze incidents, often associated with extended drought and widespread use of fire to clear land for oil palm, rubber or pulpwood plantations. In the past two decades, members of the Association of South East Asian Nations (ASEAN), particularly Malaysia, Indonesia and Singapore have experienced five major fire and haze episodes: April 1983 (Chow and Lim, 1984), August 1990 (Sham et al., 1991), June to October 1991 (Cheang et al., 1991), August to October 1994 (MMS, 1995) and September to November 1997 (Leong and Lim, 1999).

Haze episodes, which have become familiar environmental hazards in SE Asia, are the result of a combination of human activities such as forest burning in the lush tropical environment and the cyclic El Nino that causes drought, aids desiccation and facilitates high combustibility of forest resources (Odihi, 2003). These episodes have caused considerable concern amongst scientists, governments and members of the public alike. The haze is a regional air pollution phenomenon caused by emissions from biomass fires, and can be transported thousands of kilometers, affecting several countries for weeks or months, and causing the ambient air quality thresholds to exceed critical limits on a regional scale (e.g., Heil and Goldammer, 2001; Heil et al., 2006).

During the 1997 El Nino episode, up to 300 million people across the SE Asia region were exposed to elevated haze levels. More than five times the normal cases of respiratory diseases were observed in Malaysia in September alone (Awang et al., 2000). Particulate matter levels during the 1991 and 1994 smoke haze episodes in the Klang Valley, for example, were more than twice the ambient air quality standard for particulate matter smaller than 10µm diameter (PM_{10}) (Soleiman et al., 2003). Even in 'normal' (non-El Nino) years, fires in Indonesia adversely affect the air quality in Indonesia and in neighbouring countries.

The effects of haze include impacts on health, biogeochemical cycles (e.g., carbon cycle), weather and climate, tropospheric ozone, atmospheric chemistry, and rainwater acidity. The worst haze episodes in SE Asia occurred in 1997 and 1998, but forest fires in Mexico and southern United States caused similar regional haze episodes in Central America. During the 1997 to 1998 period, forest fires were also reported in Brazil, Spain, Greece, Australia, Mongolia and Russia (Radojevic, 2003a). In view of the growing incidences of biomass fires and the resulting haze throughout the world, there is need for a greater understanding of the various aspects of these phenomena, including their chemistry.

2.2. Causes of biomass burning

Forests are the major fuel source of biomass burning. The sources of forest burning in SE Asia are readily definable, but there has been continuing debate about how far each is responsible for the fires. Jones (2006) has divided the sources into three groups:

(i) traditional cultivators :
  a. who burn their small plots of land after harvest to rejuvenate the soil and to kill pest and weeds;
  b. shifting cultivators, who practise customary slash and burn methods to clear a stretch of scrub forest for cultivation (known as swidden agriculture);
  c. indigenous peoples, who burn plantations as a protest at seeing their ancestral land (for cultivation or hunting and gathering), taken away from them;

(ii) small scale investors (e.g., pioneer and migrant farmers), who are given some inducement to clear land for planting oil palm, seeds and saplings by plantation companies. These cultivators are more likely to cause widespread burning, since, unlike the traditional shifting cultivators, they have not developed practices to limit the spread of the fire once ignited, and

(iii) large scale investors (e.g., timber companies) with concession rights to harvest timber in a rainforest area. The remaining trees and bushes in the concession areas are burned to clear for the replanting with fast growing species for commercial purposes. Likewise, the oil palm companies also clear the rain forest in order to establish extensive palm oil estates.

It was estimated in a World Bank study that during the forest fires in 1997 and 1998, the shifting cultivators, the migrant, pioneer and other commercial small farmers and land developers in the transmigration programme were responsible for 25%, 17% and 8% of the total area burnt, respectively. Plantation companies were estimated to initiate 34% of the fires. Burning of timber by locals as a protest against expansion by oil palm plantations accounted for 14% of the total aggregate, with the remaining 2% due to natural causes (World Bank, 2002).

2.3. Harmful effects of forest burning

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 that diminishes the horizontal visibility, giving the atmosphere a characteristic opalescent appearance (MMS, 1995). PM_{10} can be involved in chemical reactions in the atmosphere producing secondary pollutants (Soleiman et al., 2003).

The various environmental impacts of haze from biomass fires, and especially the health effects, depend on the physicochemical properties of emissions from forest fires and the resultant haze, which has a number of harmful consequences that have been well-documented by international environmental and health organisations (Jones, 2006). Most of the information to date comes from air quality stations in regions affected by haze. These stations routinely monitor the concentrations of criteria pollutants: PM_{10}, SO_2, NO_2, CO, and O_3 (Radojevic, 1998). Many potentially harmful compounds may be present at trace levels in gases and smoke particles emitted by forest fires and these have generally not been determined during haze episodes resulting from biomass fires (Radojevic, 2003a).

The forest and peat fires, together with the associated haze produced numerous potential impacts, including health effects, reduced visibility resulting in transportation accidents and closures of airports, loss of biodiversity, lower productivity (agricultural, industrial, commercial), downturn in tourism, economic costs, effects on rainwater acidity, effects on weather and climate, effects on global cycles (e.g., carbon), and impacts on people's lifestyle (Radojevic, 2003b). However, the harm is not only confined to the areas of burning but also to other areas and countries far removed from the fires. The most serious concern was the effect upon public health, especially as a result of breathing in pollutants in the smoke from forests fires. These include upper respiratory tract infections, bronchial asthma and a decrease in lung function. In addition, evidence has been cited that the smoke damages the skin and cardiovascular system (Radojevic, 2003b).

No less serious has been the detrimental effects upon the climate, agriculture and bio-diversity. The combined effects of El Nino, smoke and reduced sunlight severely affect photosynthesis in plants. Burning that exposes the soil causes erosion and flooding. All these factors serve to reduce the productivity of agriculture (Kurniawan, 2003). In addition, the SE Asia rainforests provide a habitat for a wide variety of plant and animal life, some of which are endangered or rare. Friends of the Earth (FE) and the World Bank have contended that forest fires have further threatened the survival of many endangered or rare species (FE, 1998).

2.4. Biomass Combustion Chemistry

The fuel for biomass fires includes various types of vegetation (trees, cultivated plants, bushes, grass), peat and lignite coal. Forest fires in SE Asia generally occur in regions of peat swamps and underground lignite coal deposits. Combustible components of vegetation are composed mainly of cellulose and hemicellulose (5-70% of dry matter). Other components include lignin (15-30%), nucleic acids, amino acids, volatile extractables (aldehydes, alcohols, terpenes), minerals (<10%) and water (<60% of fresh matter). Dry plant matter can be approximated to the empirical formula CH_2O but it also includes the following elemental constituents: N (0.3-3.8% w/w), K (0.5-3.4% w/w), S (0.1-0.9% w/w), and P (0.01-0.3% w/w) (Radojevic, 2003a).

Under ideal circumstances, combustion of biomass should lead only to CO_2 and H_2O:

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

However, incomplete combustion also releases CO and many unburned hydrocarbons. S and N present in the biomass are converted to oxides during the combustion process:

$$S + O_2 \rightarrow SO_2$$

$$2N + O_2 \rightarrow 2NO$$

$$2(CH_3)_3N + 11\tfrac{1}{2}\,O_2 \rightarrow 6CO_2 + 9\,H_2O + 2NO$$

Nitrogen present in amino acids is mainly converted to NO during biomass combustion. At very high temperatures NO_x species may also result from the reaction of N_2 in the air, according to the Zeldovich chain reaction mechanism:

$$O_2 \leftrightarrow 2O^{\cdot}$$
$$O + N_2 \leftrightarrow NO + N$$
$$N + O_2 \leftrightarrow NO + O$$

The chain reaction is initiated by the atomic oxygen, which is formed from the dissociation of O_2 molecules at high temperatures reached during the flaming stage. However, high temperatures required for the Zeldovich mechanism are generally not expected in most biomass fires, except perhaps in very intense flames (Lobert and Warnatz, 1993). Although some NO_2 may be formed during combustion, most of it results from the oxidation of primary NO in the atmosphere.

A forest fire goes through several stages:
Ignition → Flaming → Smouldering → Extinction

Most emissions take place during the flaming and smouldering stages. These two processes are quite different in appearance, types of chemical reactions involved, and products emitted. The flaming stage is characterised by high temperatures and visible flames, while temperatures are much lower during smouldering and the fire burns without any visible flames (Radojevic, 2003a). During flaming, peak temperatures can be as high as 1800 K, producing emissions rich in H_2O, CO_2, NO, N_2O and N_2, along with particles high in elemental carbon. In general, reactions tend to go more to completion during the flaming stage and some of the more oxidised forms are released. Water and volatile extractables (e.g., alcohols, aldehydes and terpenes) are volatilised from the fuel material in an initial drying/distilling process. The subsequent pyrolytic step causes high temperature cracking of the fuel molecules. During this stage, components of high molecular mass are decomposed to compounds of low molecular mass. Char and tar products of intermediate molecular mass are formed and these serve as a primary energy source for the flame process, eventually decomposing to gaseous products (Radojevic, 2003a). Gaseous hydrocarbons react with reactive atoms and radicals (e.g., OH*) formed in the hot regions of the flame. Unstable radicals formed during these reactions quickly decompose to more stable, smaller hydrocarbon radicals (e.g., CH_3, C_2H_5), which are slowly oxidised to H_2O, CO, and CO_2. CO_2 is formed by oxidation of CO by OH* radicals to produce hydrogen radical:

$$CO + OH^* \rightarrow CO_2 + H^*$$

CO can form in fuel-rich parts of the flame and at temperatures too low for the formation of OH* radicals. Flaming takes place under high access of oxygen (≤15%).

Consumption of the biomass, buildup of charcoal layers on wet surfaces, increase in ash content, and the loss of volatile gases during flaming cause the flame to cease. This slows the rate of pyrolysis leading to the formation of less flammable products and lower temperatures characteristic of the smouldering stage, which can persist for several days. During smouldering a large quantity of incompletely oxidised compounds is emitted: CO, CH_4, non-methane hydrocarbons, polynuclear aromatic hydrocarbons (PAHs), CH_3Cl, H_2S, COS, $(CH_3)_2S$, $(CH_3)_2S_2$, amines, heterocycles, amino acids, and particles low in elemental carbon. Smouldering can take place at oxygen concentrations as low as 5% in densely packed fuel beds. CO is formed by low-temperature surface reaction of O_2 with carbon, and it cannot be oxidised to CO_2 to the same extent as during the flaming stage.

Other than temperature, a number of other factors can influence biomass fires and the emissions produced: the type of vegetation, its water content, density and structure; weather (e.g., lightning can start fires while heavy rains can put them out, wind speed can determine whether the fire is static or moving); and topography (fires behave differently on slopes than on flat surfaces). The water content of the plant material is especially important as it can determine the burning efficiency. High water content may prevent a plant from igniting, or it may reduce flaming while enhancing smouldering combustion. Density and structure are also important; for example, high-density stem wood is more difficult to ignite than low-density grasses.

CO and CO_2 are the major carbon containing compounds released by biomass combustion, followed by hydrocarbons, carbon associated with particulate matter (soot), and other minor substances. Generally, more than 95% of carbon emitted by biomass fires is in the form of CO and CO_2. Smoke particles emitted during biomass combustion are generally <10 μm in diameter. Studies of biomass fires reveal that the particles cover a broad size spectrum. Particles from 0.01 to 43 μm in diameter have been measured with a pronounced number concentration peak at 0.15 μm (Ward, 1990). Between 40 and 95% of the mass of particles consists of particles <2.5 μm in diameter, while particles >2.5 μm but smaller than 10 μm account for less than 10% of the particle mass (Ward 1990). Numerous trace metals are also emitted during biomass combustion.

Levine (1999, 2000) measured the emission of gases (CO, CO_2, CH_4 and NO_x) and particles from Kalimantan and Sumatra during the 1997 haze episode and concluded that these emissions significantly exceeded those from the Kuwaiti oil fires of 1991. These emissions could have a significant impact on tropospheric chemistry. The general chemistry of the atmosphere is dominated by photochemical reactions initiated by solar radiation. Free radicals (e.g., OH^*) play a fundamental role in many of the pollutant transformation mechanisms. The $OH^\bullet$ radical is highly reactive and a strong oxidising agent for a variety of pollutant gases (e.g., SO_2, NO_X). Production of OH^* radicals is initiated by the photolysis of O_3. Sunlight with wavelengths <315 nm splits O_3 into an O_2 molecule and singlet atomic oxygen O (^{1}D) which can react with water vapour to form OH^* radical:

$$O_3 + h\upsilon\ (\lambda < 315\text{ nm}) \rightarrow O_2 + O(^1D)$$
$$O(^1D) + H_2O \rightarrow 2OH^*$$

OH^* radicals can also be formed by other atmospheric reactions (photolysis of HNO_2, photolysis of H_2O_2, etc.). The OH^* radical is involved in the oxidation of SO_2 to H_2SO_4, oxidation of NO_X species to HNO_2 and HNO_3, and the oxidation of CO to CO_2.

The H atom can react with O_2 to produce the hydroperoxy radical (HO_2^*), another reactive species:

$$H + O_2 \rightarrow HO_2^*$$

The HO_2^* radical is a strong oxidising agent and it is involved in several important atmospheric reactions, including the oxidation of NO to NO_2. Free radicals such as OH^* and HO_2^* also react with organic pollutants emitted by combustion processes (hydrocarbons, aldehydes, etc.). Aldehydes and PAHs may be emitted directly by combustion processes or they may be produced by atmospheric reactions of primary pollutants.

NO_2 is photolysed to produce O (^3P) which reacts with O_2 to produce O_3:

$$NO_2 + h\upsilon\ (\lambda < 435\ \text{nm}) \rightarrow NO + O\ (^3P)$$

$$O\ (^3P) + O_2 + M \rightarrow O_3 + M$$

where M is a third body reactant. O_3 reacts rapidly with NO to produce NO_2:

$$NO + O_3 \rightarrow NO_2 + O_2$$

2.5. Haze characteristics and properties in Southeast Asia

The particle size distribution of the 1997 smoke-haze, an important parameter with respect to health impacts, atmospheric residence time and visibility impairment, was poorly investigated. Simultaneous PM_{10} and total suspended particulate matter (TSP) measurements at the Malaysian Meteorological Services (MMS) site in Petaling Jaya/Kuala Lumpur showed a clear trend to higher PM_{10}/TSP ratios when PM_{10} concentration increased during the smoke-haze episode 1997. Table 2.1 shows that from July to mid-November (haze episode), the PM_{10} fraction contributed on average 66% to the TSP mass (Heil and Goldammer, 2001).

At concentration exceeding 150 $\mu g\ m^{-3}$ PM_{10} ('$PM_{10} > 150$'), the PM_{10}/TSP ratio ranged between 70 and 93% (mean 78%). During 'post-haze' conditions (mid-November to December), it was only 46%. The fraction TSP minus PM_{10} remained almost constant during and after the smoke-haze episode (48 versus 45 $\mu g\ m^{-3}$); apparently, the increase in TSP concentration was almost entirely attributed to the PM_{10} fraction (Heil and Goldammer, 2001).

Table 2.1 Concentrations of PM_{10} and TSP during and after the smoke haze episode at Petaling Jaya, 1997

	Haze (1 Jul – 15 Nov)		Post-haze Total
	Total	$PM_{10} > 150$	(16 Nov – 31 Dec)
PM_{10}	107 (28 – 424)	247 (153 – 424)	38 (22 – 56)
TSP	155 (52 – 525)	314 (204 – 525)	83 (51 – 117)
PM_{10}/TSP (%)	66 (26 – 93)	78 (70 – 93)	46 (33 – 70)

Notes: Mean (and range) concentrations in $\mu g\ m^{-3}$
Source: Heil and Goldammer (2001)

The concentrations of PM_{10} and major gaseous pollutants (SO_2, NO, NO_2, CO and O_3) determined using instrumental methods by Radojevic and Hassan (1999) in Brunei during the 1998 haze episode are summarised in Table 2.2.

Table 2.2 Range of hourly concentrations of major air pollutants in Brunei Darussalam determined using instrumental methods

Pollutant	PM_{10}	SO_2	NO	NO_2	O_3	CO
			Haze			
Range	1.2-999	0.78-87.3	6.8-97.2	5.8-99.1	5.1-99.9	1.2-21.9
Mean	109.9	7.27	19.9	41.5	63.2	4.2
			Non-haze			
Range	9.0-393	3.6-23.3	6.6-90.4	3.6-99.4	1.4-97.0	0.6-2.77
Mean	20.4	5.24	20.8	28.6	48.5	1.29

Notes: All concentrations in $\mu g\ m^{-3}$ except CO in $mg\ m^{-3}$
Source: Radojevic and Hassan (1999)

The concentration ranges of organic micropollutants adapted from Muraleedharan et al. (2000) are summarised in Table 2.3.

The 24-hour average PM_{10} concentrations at Bandar Seri Begawan (BSB) during the course of the 1998 episode adopted from Radojevic (2003a) are illustrated in Figure 2.1. Also shown are the concentrations determined in Seria, Brunei during the month of April 1998, when the haze was especially severe.

Table 2.3 Concentration ranges of organic micropollutants in haze during the 1998 haze episode in Brunei and recommended guideline values

Pollutant	Concentration (µg m^{-3})	Recommendation/ guideline (µg m^{-3})	Authority
TPHs	<0.1–307	-	-
Acetic acid	<0.1–19.4	500	Australia (Victoria)
Cresol	<0.1	-	-
Formaldehyde	<1.0–21.6	120	WHO
Acetaldehyde	<1.0–15.9	76	Australia (Victoria)
Propionaldehyde	2.0–17.0	-	-
Butyraldehyde	2.8–71.6	-	-
Benzene	<0.1–24.8	1.2	US EPA (long-term goal)
Toluene	<0.1–15.5	260	EU (proposed limit)
Ethyl benzene	<0.1–2.01	20	Russia
Xylenes	<0.1–28.7	200	Russia
Phenol	<0.1–0.41	100	US EPA
PAHs (total)	1.0–33.8	0–0.1	USA
Naphthalene	0.5–29.8	1000	Australia (Victoria)

Source: Muraleedharan et al. (2000)

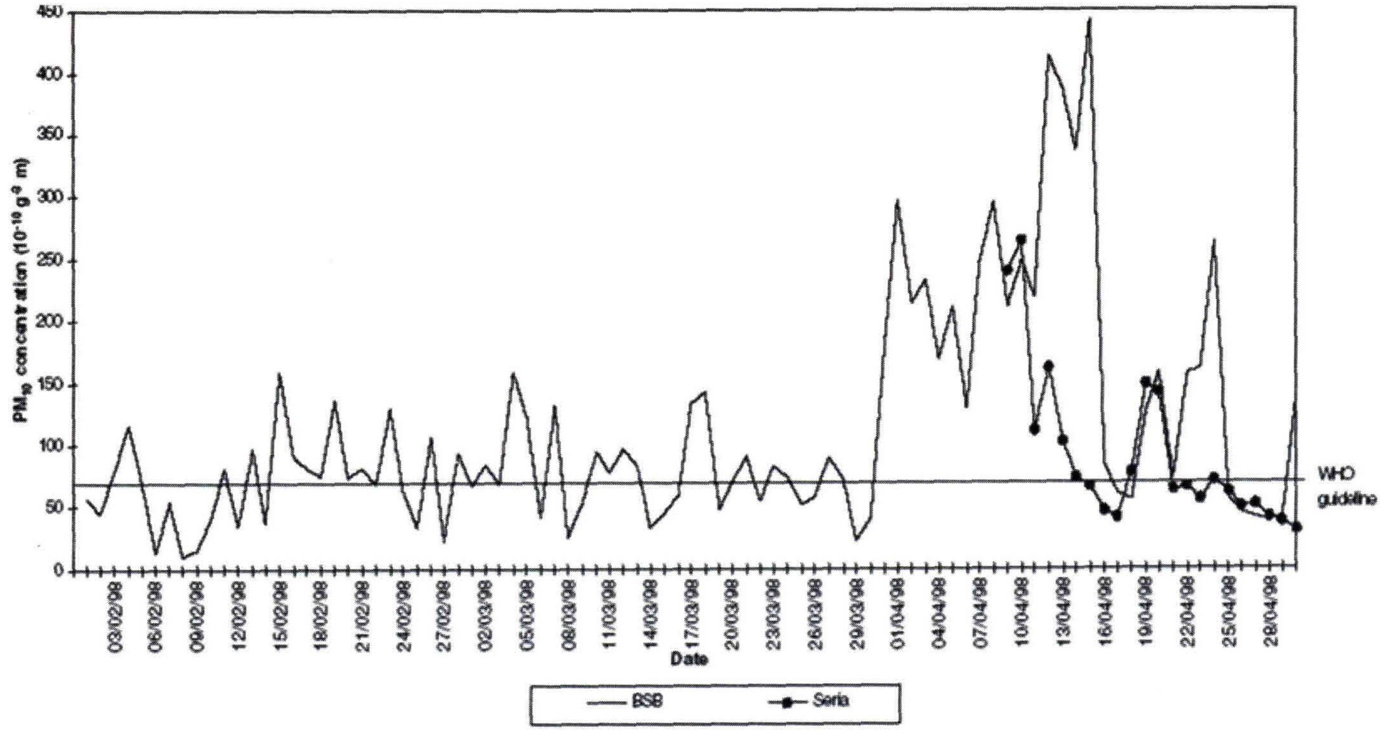


Figure 2.1 Concentration of PM_{10} (24-h average) during the haze episode of 1998 at Bandar Seri Bagawan and Seria, Brunei

Source: Radojevic (2003a)

2.6. Chemical variations of air samples

Air samples collected from different locations in Peninsular Malaysia are listed below.

Table 2.4 Sampling dates and locations

No	Samples location	Date	Sample Code
1	Petaling Jaya	11 / 8 / 05	69968
2	Petaling Jaya	11 / 9 / 05	70410
3	Petaling Jaya	11 / 7 / 05	69667
4	Melaka	11 / 7 / 05	69064
5	Melaka	16 / 8 / 05	69076
6	Melaka	15 / 9 / 05	69086
7	Setia Wangsa	11 / 7 / 05	68878
8	Setia Wangsa	16 / 8 / 05	69099
9	Setia Wangsa	15 / 9 / 05	69109
10	UKM Bangi	-	-

Samples from Petaling Jaya, Melaka and UKM, Bangi were analysed in the UKM laboratory.

2.6.1. Analytical Procedures

The flow rate of 43 ft^3/min (1.217624m^3/ min) of the high volume sampler is used in determining the particulate matter ($\mu g/m^3$) The results are shown in Table 2.5.

The air samples were also subjected to the following analytical tests:

- X-Ray Fluorescent test (XRF) test
- Determination of organic content;
- Scanning Electron Microscope test;
- Electron Dispersive X-Ray test;and metal mapping

2.6.1.1 X-Ray Fluorescent test

Samples were collected from the used filter paper as fine powder and further ground to 20 - 30 microns for X-ray fluorescence analysis (XRF). The sample was transformed into a 32 mm diameter pressed-powder pellet, which was backed and rimmed by pure boric acid powder and pressed up to 20 tonnes to form a rigid pellet.

A standard parameter for ten major elements was set-up for a fully automated Philips PW 1480 spectrometer. However, due to insufficient number of certified reference materials (CRM's), direct comparison method (one-to-one method) instead of calibration curve method was used.

Elemental scanning of the three samples revealed that the metal content for samples collected from Petaling Jaya contained Zn, Fe, Ba, Ca Al, Si, K, C, Cl, Fe and S, while those collected from Melaka contained Zn, Ba, Ca, Fe, Ca, K, Si and C. Samples collected from UKM consisted of Zn, Fe, Ca, Si, Ca and K.

2.6.2. Determination of the weight of samples

The weight of the air samples collected varied according to dates and locations as shown in Table 2.5.

Table 2.5 Weight and concentration of air samples according to dates and locations

No	Sample origin	Date	Sample Weight (g)	Concentration of TSP (μg/m^3)
1	Petaling Jaya	11 / 8 / 05	3.4123	1.946
2	Petaling Jaya	11 / 9 / 05	2.9933	1.707
3	Petaling Jaya	11 / 7 / 05	2.9371	1.675
4	Melaka	11 / 7 / 05	2.5613	1.460
5	Melaka	16 / 8 / 05	2.7683	1.578
6	Melaka	15 / 9 / 05	2.8432	1.621
7	Setia Wangsa	11 / 7 / 05	3.4672	
8	Setia Wangsa	16 / 8 / 05	2.8601	
9	Setia Wangsa	15 / 9 / 05	2.8123	
10	UKM Bangi	-	2.8321	

2.6.3. Determination of the organic content

The organic content (percentage) is calculated based on the total solids trapped in each one cm^2 of the filter. The results are shown in Table 2.6.

Table 2.6 Total organic content of the particulates

No	Sampling point	Organic content (% cm^{-2})
1	Petaling Jaya	5.946
2	Melaka	5.526
3	UKM Bangi	3.271

Most of the organics associated with particulates were semi or non-volatile organics such as poly-aromatic or high molecular weight hydrocarbons.

2.6.4. Surface Analysis of the Particulates

Surface analysis of the filter paper was conducted by two methods. First was the Scanning Electron Microscopy (SEM) to study surface topography of the particulates. A high energy (typically 10keV) electron beam was scanned across the surface of the filter paper to visualise the shape of the particulates. The second method was by using the Energy Dispersive x-Ray (EDX). An electron beam (10-20keV) struck the surface of a conducting sample which caused X-rays to be emitted from the material. The energy of the X-rays emitted depends on the material under examination.

2.6.4.1 Scanning Electron Microscopy (SEM) test

A Scanning Electron Microscope of variable pressure, model LEO 1450 was used. The filter paper containing air sample was cut to a size of $1cm^2$ and dried in the oven at 35°C for 24 hours. The sample was then gold coated and mounted for SEM analysis.

The results showed the particulates had different shapes, most of which were like crystals with open pores, according to the sampling locations as shown in Figures 2.2 to 2.7.

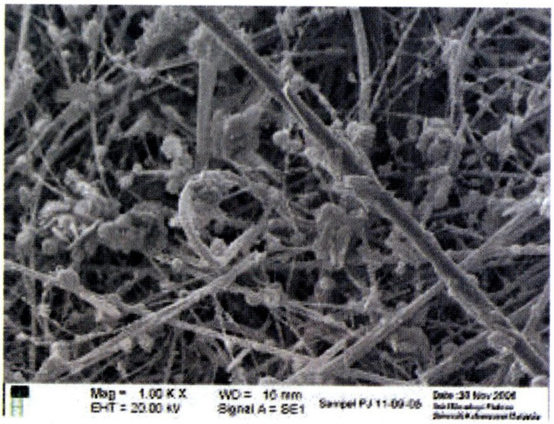


Figure 2.2 SEM results from Petaling Jaya on 11 Sept 2005 at 1000x magnification

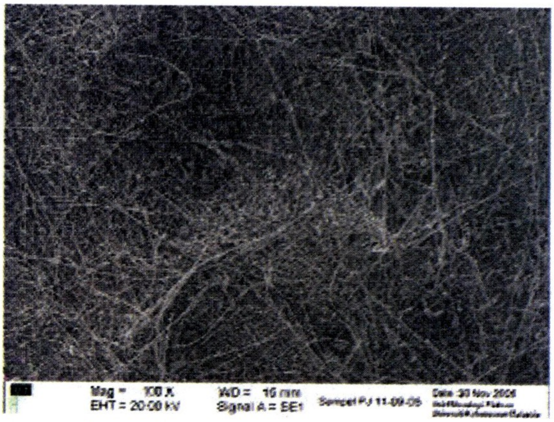


Figure 2.3 SEM result analysis from Petaling Jaya on 11 Sept 2005 at 100x magnification

Figure 2.4 SEM result analysis from Melaka on 11 July 2005 at 1000x magnification

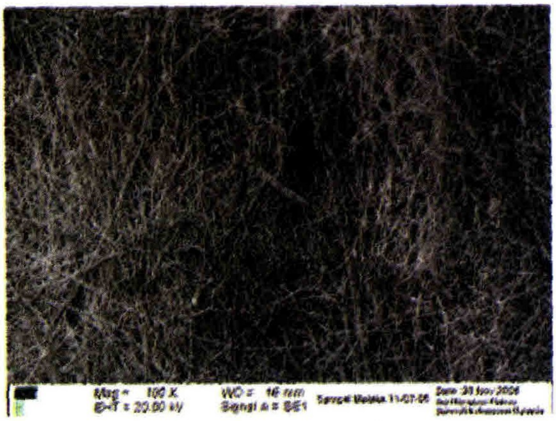


Figure 2.5 SEM result analysis from Melaka on 11 July 2005 at 100x magnification

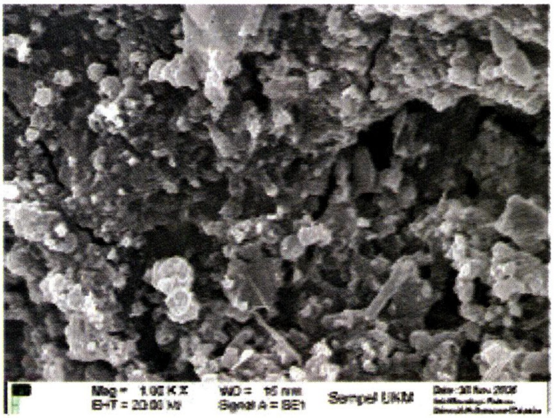


Figure 2.6 SEM result analysis from UKM Bangi at 1000x magnification

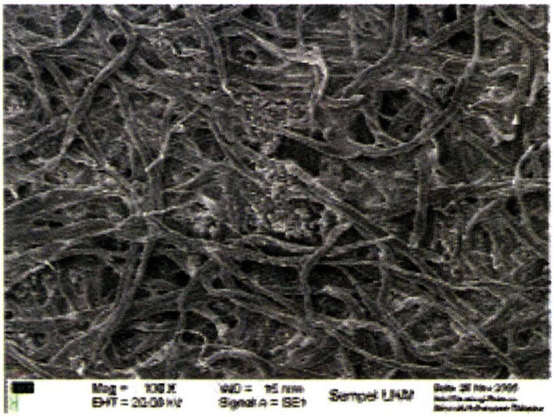


Figure 2.7 SEM result analysis from UKM Bangi at 100x magnification

2.6.4.2 Electron Dispersive X-Ray (EDX) test

The Oxford Instrument EDX used for SEM analysis provides information on the surface topography and the average atomic number. Elemental analysis of the particulates collected from

Petaling Jaya, Melaka and UKM were analysed in duplicate and presented in the following text.

2.6.4.2.1. Petaling Jaya sampling point

Heavy metals comprise 10% of the total mass weight of the samples from the EDX analysis (Tables 2.7 and 2.8), with silicon and aluminum comprising 25 to 30% of the total content.

Table 2.7 Elemental analysis by EDX for samples collected from Petaling Jaya on 11 September 2005

Element	Weight, (%)	Weight, (% of σ)	Atomic (%)
C K	49.66	3.39	73.11
Na K	6.06	0.51	4.66
Al K	2.62	0.24	1.72
Si K	21.98	1.50	13.84
S K	3.10	0.32	1.71
Cl K	0.54	0.14	0.27
K K	3.34	0.28	1.51
Ca K	3.02	0.27	1.33
Zn K	4.45	0.58	1.20
Ba L	4.73	0.53	0.61
Pb M	0.49	0.66	0.04
Totals	100.00		

2.6.4.2.2. Melaka sampling point

Heavy metals comprise 10% of the total mass weight of the samples from the EDX analysis (Tables 2.9 and 2.10), with silicon and aluminum comprising 30 to 40% of the total content.

Table 2.8 Elemental analysis by EDX for samples collected from Petaling Jaya on 11 September 2005

Element	Weight (%)	Weight, (% of σ)	Atomic (%)
C K	39.72	4.07	64.65
Na K	6.70	0.56	5.70
Al K	3.40	0.29	2.47
Si K	27.93	1.92	19.44
S K	3.14	0.33	1.92
K K	3.52	0.29	1.76
Ca K	2.68	0.25	1.31
Fe K	0.85	0.24	0.30
Zn K	5.01	0.60	1.50
Ba L	6.37	0.61	0.91
Pb M	0.68	0.67	0.06
Totals	100.00		

Table 2.9 Elemental analysis using EDX for samples collected from Melaka on 11 July 2005

Element	Weight, (%)	Weight, (% of σ)	Atomic (%)
C K	11.56	2.52	19.57
O K	40.28	1.32	51.19
Na K	4.52	0.32	4.00
Al K	2.61	0.17	1.97
Si K	26.06	0.84	18.87
K K	2.59	0.15	1.35
Ca K	1.15	0.12	0.58
Zn K	5.10	0.44	1.59
Ba L	5.58	0.38	0.83
Pb M	0.54	0.41	0.05
Totals	100.00		

Table 2.10 Elemental analysis using EDX for samples collected from Melaka on 11 July 2005

Element	Weight, (%)	Weight, (% of σ)	Atomic (%)
C K	15.29	9.79	35.63
Na K	6.10	0.90	7.43
Al K	4.69	0.64	4.87
Si K	36.58	4.31	36.46
Cl K	1.57	0.31	1.24
K K	4.71	0.63	3.37
Ca K	3.00	0.46	2.09
Fe K	1.60	0.51	0.80
Zn K	12.42	1.78	5.32
Ba L	12.76	1.71	2.60
Pb M	1.27	1.11	0.17
Totals	100.00		

2.6.4.2.3. UKM sampling point

There was limited metal content in the UKM sample although the sampling period lasted for five continuous days. High carbon content indicated an organic flyash with less metal content.

Table 2.11 Elemental analysis using EDX for samples from UKM

Element	Weight, (%)	Weight, (% of σ)	Atomic (%)
C K	57.97	0.97	67.83
O K	32.04	0.88	28.15
Al K	1.61	0.10	0.84
Si K	5.14	0.16	2.57
K K	0.75	0.08	0.27
Fe K	0.95	0.15	0.24
Pb M	1.56	0.33	0.11
Totals	100.00		

Table 2.12 Elemental analysis using EDX for samples from UKM

Element	Weight, (%)	Weight, (% of σ)	Atomic, (%)
C K	58.32	0.90	67.55
O K	34.36	0.84	29.88
Al K	0.88	0.08	0.45
Si K	3.52	0.12	1.75
K K	0.26	0.07	0.09
Cu K	0.63	0.19	0.14
Pb M	2.04	0.33	0.14
Totals	100.00		

2.6.4.3. Metal Mapping

Mapping technique is used to obtain the distribution of the metal scatterings on the outer surface of the particulates. The results showed that the quantity of metals within the molecular structure of materials in the particulate matrix on the outer surface of particulates provided specific characteristics to the nature of haze. Mapping is demonstrated in several colour indications related to each metal. Colour density can give a relative idea on metal concentration.

2.6.4.3.1 Petaling Jaya sampling point

The sample collected from Petaling Jaya on 11 September 2005 was subjected to metal scanning. A sample of ash was scanned and it exhibited an elemental content as illustrated in the following colour indicator. Colour intensity is related to element concentration in the particulate matrix as presented below.

Sampel PJ 11-09-05-I

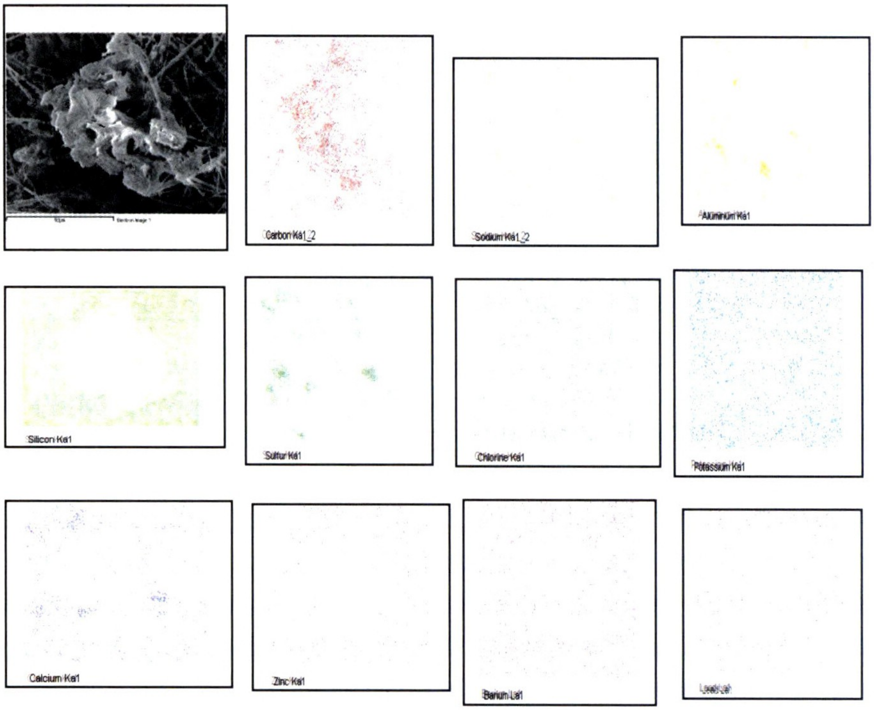


Figure 2.8 Results of metal mapping analysis I on samples collected from Petaling Jaya on 11 September 2005

Sampel PJ
11-09-05-II

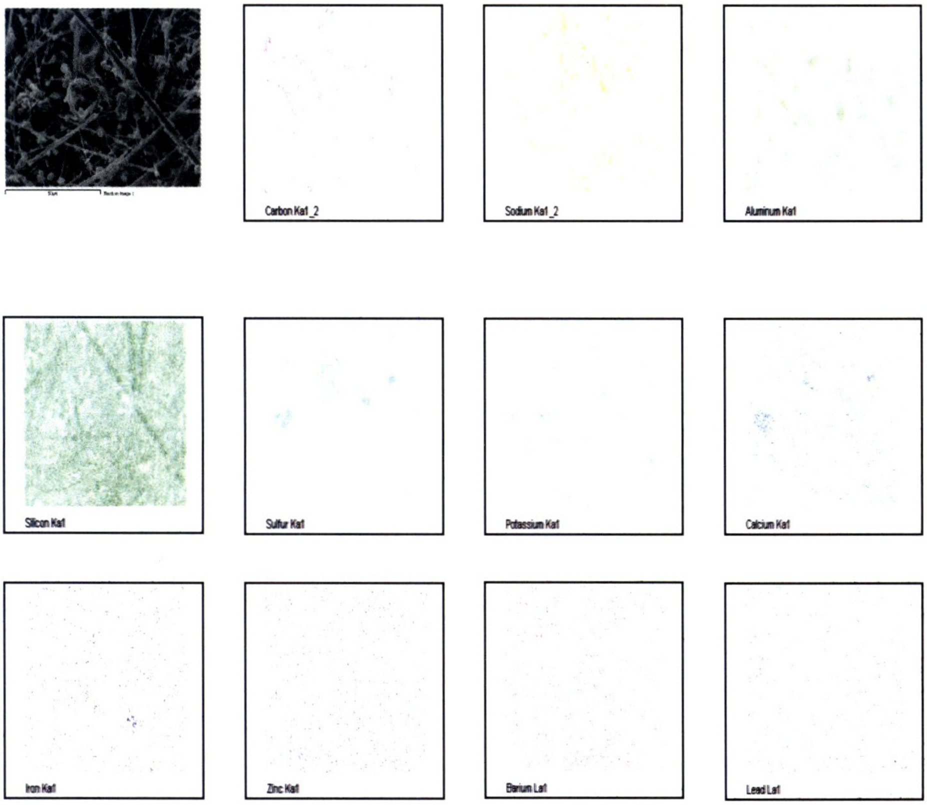


Figure 2.9 Results of metal mapping analysis II on samples collected from Petaling Jaya on 11 September 2005

2.6.4.3.2. Melaka sampling point

The sample collected from Melaka on 11 July 2005 was subjected to metal scanning and the results are shown below (Figure 2.10).

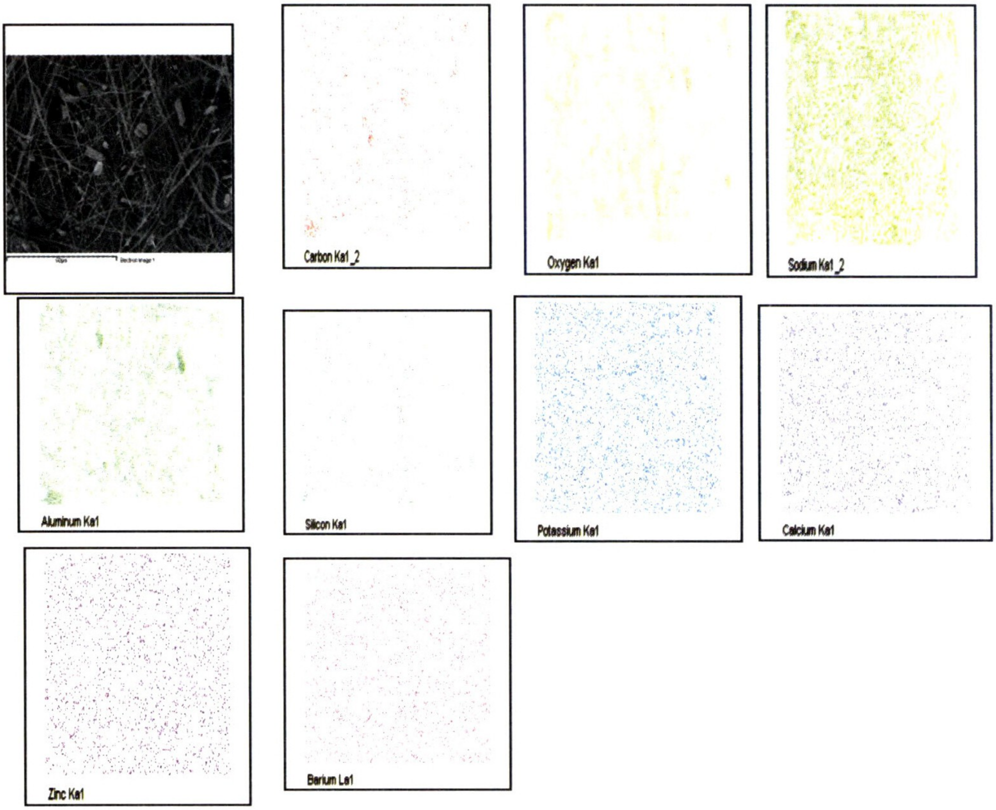


Figure 2.10 Results of metal mapping analysis I on samples from Melaka on 11 July 2005

Sampel Melaka 11-07-05-2-II

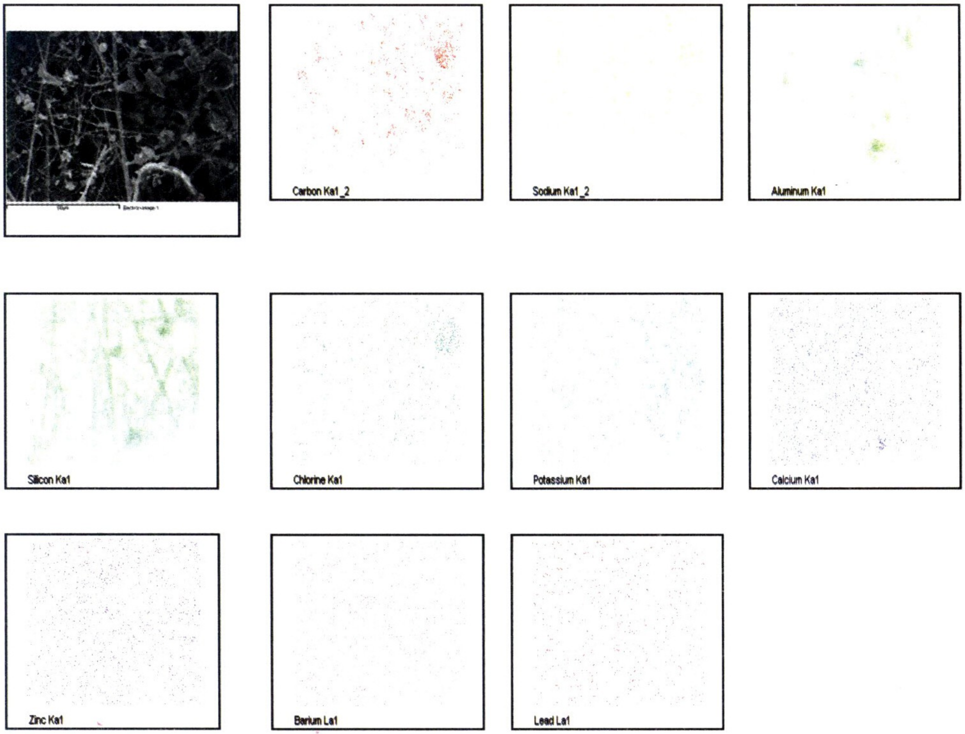


Figure 2.11 Results of metal mapping analysis II on samples from Melaka collected on 11 July 2005

2.6.4.3.3 UKM sampling point

The samples from UKM, Bangi were collected on five continuous days from 21 to 26 August 2006. The results of metal mapping of samples collected from UKM Bangi were different from those collected from Petaling Jaya and Melaka stations, exhibiting less chemical variations. Carbon is the main content followed by aluminum. Traces of lead and iron were detected, which were absent in the Petaling Jaya and Melaka samples.

Sampel UKM I

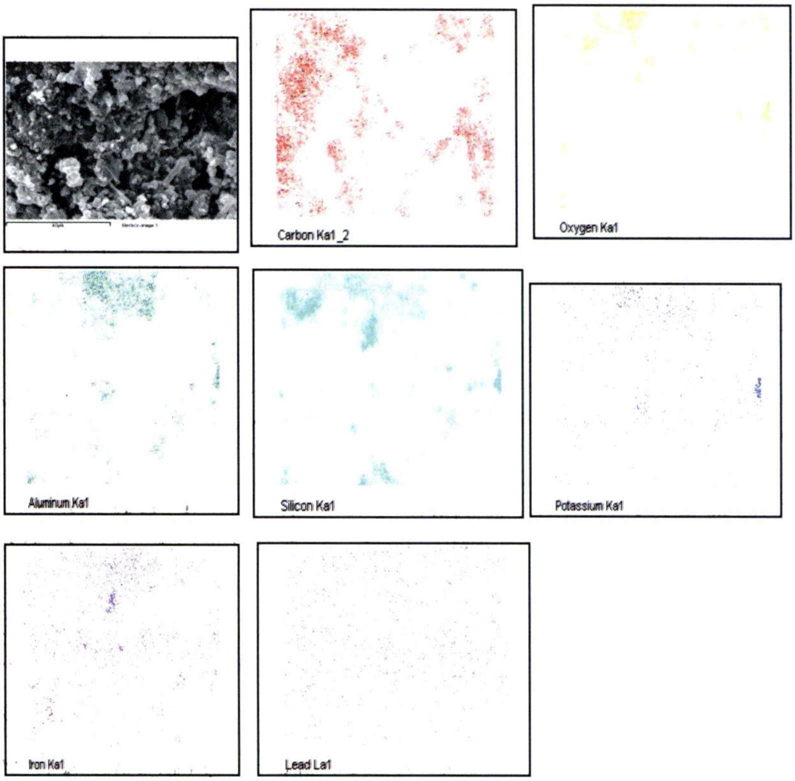


Figure 2.12 Results of metal mapping analysis I on samples collected from UKM Bangi

Sampel UKM II

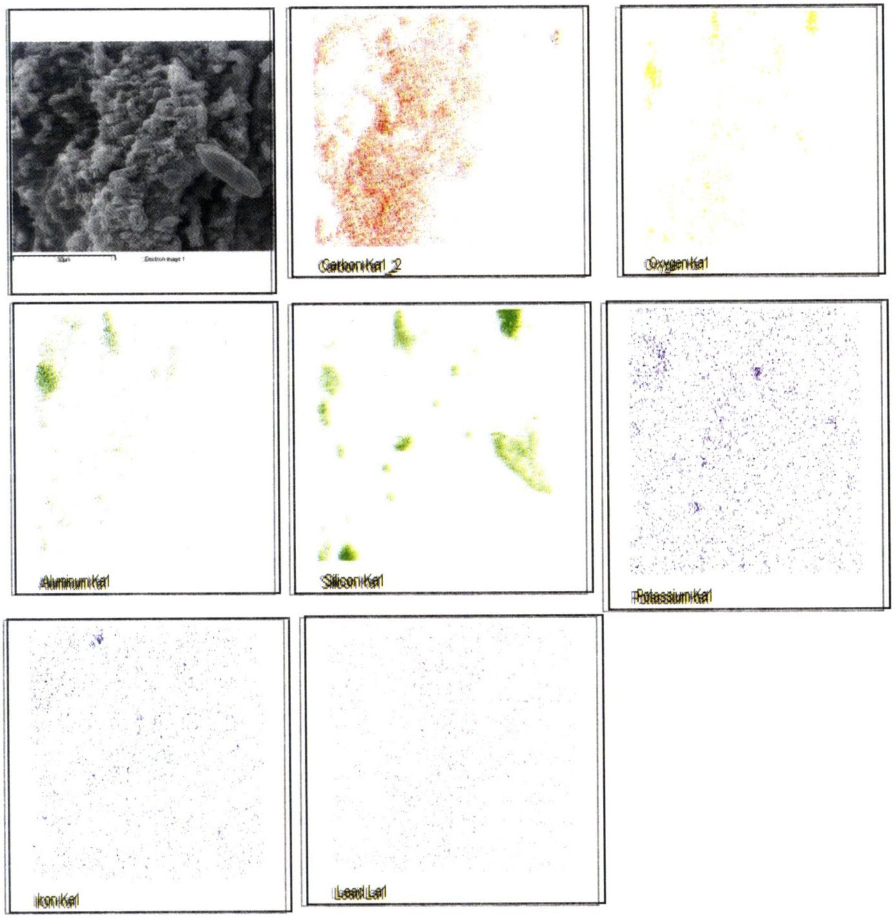


Figure 2.13 Results of metal mapping analysis II on samples collected from UKM Bangi

2.6.5. Neutron Activation Analysis

This method of analysis is very effective for elemental determination, whereby the sample is subjected to a flux of neutrons and the gamma activities measured. A weight of 0.1061gram of precipitates was collected from the filter paper and subjected to neutron activation. Data collected in first and second counts is presented in Table 2.13.

Table 2.13 Neutron activation analysis of air samples

Element	Energy of activation (KeV)	Concentration (ppm) First count	Concentration (ppm) Second count
Dy-165	95	3.90	-
Sm-153	103	5.10	5.1
Eu-152m	122	1.00	1.0
Ga-72	834	-	10
Ba-139	166	159.00	-
Ti	320	3,000	-
Sr-87	388	108	-
I-128	443	0.00	-
Br-90	617	7.00	-
Mg-27	1014	11,300	-
Na-24	1368	2,400	2,400
V-52	1434	66	-
K-42	1524	12,100	12,100
Al-28	1779	47,000	-
Mn-56	1811	631	631
Cl-38	2168	0.00	-
Ca-49	3083	163,000	-

Results in Table 2.13 exhibit a high reading of aluminum and also significant titanium content. Heavy metals such as vanadium, magnesium, and manganese are present in relatively high concentrations.

2.7. Conclusion

Samples were collected from several sampling points during the 2005 haze episode and subjected to chemical content analysis. The UKM sampling point was used as a reference.

The main issue in the chemical analysis is the high content of aluminum and silicon metals. This reflects the major ash content during forest and agro-wastes burning. Vanadium, a toxic metal was observed at relatively medium concentration, while heavy metals such as Zn, Mg, Mn were observed in high concentrations. Most of these metals were in the form of oxides and carbonates as indicated by the high oxygen and carbon content. There was a record of sulfur, which could help in the prediction of some metals present in a form of sulfates or sulfides. Organic content is relatively small, comprising 5% of the total weight. Most the organics were of high molecular weights and most likely to be polyaromatics that were chelated to the metals.

Further investigation is required to ascertain the chemical molecular structures. Anionic determination such as for carbonates, sulfates as well as oxides is required to ascertain the molecular structure of the haze particles.

CHAPTER 3

Effects of Haze on Human Health in Malaysia: Case Study in 2005

Norela Sulaiman, Saidah Md Said and Mohd Talib Latif

3.1. Introduction

The biomass burning in the South East Asian region has been reported since the late 19th Century (Potter, 2001). Droughts and fires have always been a part of the natural environment in this area. Von Gaffron (1846) reported almost 600,000 ha of swamp forest burning for months during the drought of 1846, which he witnessed while exploring the Kotawaringan district for coal and gold deposits (Potter, 2001). Extensive haze in 1902 and fires was reported by Braak (1929) during the drought of 1914. Since then, several major forest fires in South East Asia were recorded in 1972, 1987, 1990, 1994, 1997, 2004 and the last one was in July/August 2005 (Heil, 2000; Heil and Goldammer, 2001).

Biomass combustion is an important primary source of many trace substances that are reactants in atmospheric chemistry. Soot particulate matter decreases visibility and absorbs incident radiation. Chemically, biomass smoke particles contain thermally unaltered and partially altered biomarker compounds from the vegetation and can change climate by altering the radiation balance (von Hoyningen-Huene, et al., 1999). In urban atmosphere, particles collected in haze conditions are derived both from biomass combustion and vehicular emissions, which influence the human health.

Vegetation is the major fuel consumed in biomass burning and is composed predominantly of cellulose, hemicellulose and lignin. Together, these three polymeric materials account for over 90% of the dry weight of most vascular plants, with the remaining mass being composed of various lipids, protein, and other metabolites, as well as mineral and water. The combustion of organic components of biomass involves a complex series of physical transformations and chemical reactions including pyrolysis, depolymerisation, water elimination, fragmentation, oxidation, char formation and votalisation (Graham, et al., 2002, Shafizadeh, 1984). Gaseous compounds released include carbon dioxide (CO_2), carbon monoxide (CO), oxide of nitrogen (NO_x), ammonia (NH_3), hydrogen (H_2) (Heil and Goldammer, 2001).

The organic material within smoke aerosols is composed of a highly complex mixture of compounds covering a wide range of molecular structures, physical properties, and reactivity. Numerous studies, predominantly laboratory based, have contributed towards knowledge of the organic products of biomass combustion. Research by Graham et al. (2002) on water soluble organic compounds (WSOC) of aerosols collected in the Amazon Basin during the 1999 burning season indicates that the product of biomass burning is a complex mixture of oxygenated compounds derived primarily from biomass burning.

Combustion from biomass burning during haze episodes also distributes carcinogenic substances such as polycyclic aromatic hydrocarbon (PAH). According to Reisen and Brown (2006), during the haze episode in Indonesia, PAH levels were recorded 3 to 36 times higher than normal. In Kuala Lumpur, PAH measurements were found to be eight times higher during hazy episode than those recorded on clear days, while the levels of benzo(a)pyrene were 15 times higher than normal (Omar, et al., 2006). Obstruction of sunlight also occurs during haze episode and may promote the spread of harmful bacteria and viruses that would otherwise be killed by ultraviolet B (Afroz, et al., 2003).

3.2. Haze and Health Implications

The generally established constituents of haze comprise a large variety of chemical pollutants such as particulate matter (<10 mm), which is the most consistently elevated pollutant in haze episodes, inorganic gases such as SO_2 and NO_2, hydrocarbons, aldehydes and polycyclic aromatic hydrocarbons (PAH), with benzopyrene being the most carcinogenic (Stephen and Low, 2002). When these gases are inhaled, the reaction between the fluid (water) and the gases in the lung will form an acidic media and this will trigger spontaneous reactions in the lung parenchyma, which would result in the constriction of the alveoli. Patients will experience difficulty in breathing and wheezing (Ishak and Ooyub, 2002).

The Malaysian Ministry of Health has identified some diseases, which are common and most likely to increase during the haze episode due to the direct relationship between the disease and the haze constituents. The most significant immediate health impacts of haze are respiratory or eye-related illness such as asthma, bronchitis, upper respiratory infections (URI) and conjunctivitis (Stephen and Low, 2002). The most significant immediate health impacts of the 1997 haze in Indonesia were upper respiratory infections (URI), bronchial asthma, diarrhea, eye irritation and skin diseases. The number of upper respiratory infections (URI) cases decreased significantly in parallel with the decrease in the incidence of forest fires (Aditama, 2000). Humans exposed to hazardous air during forest fires are most likely to develop signs and symptoms of upper respiratory tract infections (URTI), asthma, conjunctivitis and increased risk of mortality related with heart problems (Ishak and Ooyub, 2002). Asthma, upper respiratory tract infections (URTI) and conjunctivitis are sensitive variables that can be used as a proxy indicator to assess the quality of air in Malaysia (Ooyub, et al., 2005).

Several other studies indicated the effects of air pollution in Malaysia on human health especially related to suspended particulate matter and haze conditions (Afroz, et al., 2003; Mott, et al., 2005; Omar, et al., 2006; Sastry, 2002). The toxicity effect of dust from biomass burning as compared to dust from vehicles and industries is still being debated (Vedal and Dutton, 2006). There are clear indications of increasing trend of patients with acute respiratory infections and asthma seeking treatment from hospitals during haze episodes (Brauer and Hisham-Hashim, 1998; Heil and Goldammer, 2001; Latif and Othman, 2001). Research by Motte et al. (2005) in Sarawak between 1995 to 1997 found significant increases in respiratory hospitalisation during the 1997 haze episode, particularly for asthma patients in the 19 to 39 years and 40 to 64 years age categories. Survival analyses indicate that persons over the age of 65 years with prior hospitalisations for respiratory diseases are more likely to be re-hospitalised than others.

3.3. Air Pollutant Index (API) and Health Indicators

The APIs indicate the relationship between air pollutants and human health based on individual concentrations of PM_{10}, carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3). As indicated by the concentrations of PM_{10} and gases during the 1997 haze episode in Malaysia, PM_{10} concentration was the main contributor of API (based on the value above 100 as indicated in Table 1). Latif, et al., (2006) recorded the the sub-index of PM_{10} to be highest in the API for Malaysia in most cases.

Table 3.1 The API values and their relation to human health

API	Status	Level of Pollution
0-50	Good	Low pollution with no ill effects on human health
51-100	Moderate	Moderate pollution with no ill effects on human health
101- 200	Unhealthy	Mild aggravation of symptoms among high risk persons, i.e. people with heart or lung diseases
201-300	Very Unhealthy	Significant aggravation of symptoms and decreased exercise tolerance in persons with heart and lung diseases
301-500	Hazardous	Severe aggravation of symptoms and endangers health
Above 500	Emergency	Severe aggravation of symptoms and endangers health

3.4. Case Study in 2005

In August 2005, the Southeast Asian Region experienced the worst haze episode since 1997. Smoke from forest fires on the Indonesian island of Sumatera was identified as the primary cause of the haze. On 11 August 2005, a state of emergency was announced for the world's twelve largest port, Port Klang and the district of Kuala Selangor after the API reached dangerous levels (defined as a value greater than 500). This was a first time a haze emergency was imposed in Peninsular Malaysia since the September 1997 haze, when Sarawak was placed in a state of emergency due to similar reasons.

Comparisons of air quality data (PM_{10}) from several meteorological stations e.g. Bayan Lepas, Pulau Pinang; Tanah Rata and Kuantan, Pahang; Senai, Johor; Petaling Jaya, Selangor; Kota Kinabalu, Sabah and Kuching, Sarawak showed that there were signs of increasing trend of PM_{10} at all stations (Figure 3.1), especially at Petaling Jaya, located on the west coast of Peninsular Malaysia and close to Sumatera. Petaling Jaya is also located in the Klang Valley, which is the most developed region in the country and has the highest concentration of population. In addition, these areas also have the highest number of registered vehicles; thus, anthropogenic sources of air pollution is readily high (Kassim, 2002).

3.5 Meteorological Factors

According to Abidin, et al. (1989), the concentrations of PM_{10} were higher during the dry southwest monsoon period when the total volume and frequency of rainfall was lowest (Figure 3.2). Dry spells from June until September 2005 could have led to more forest fires in Indonesia, especially in Sumatera and Kalimantan.

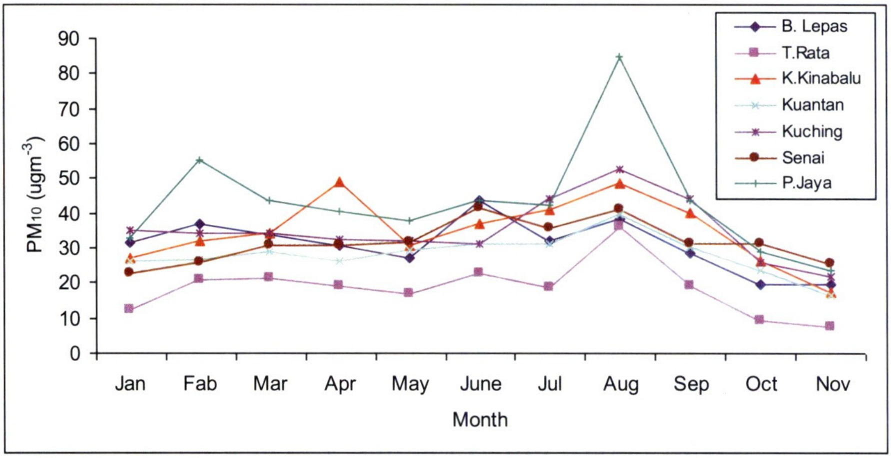


Figure 3.1 Levels of suspended particulates (monthly) recorded from January to November 2005

3.6. Haze and Health Effects

Studies that relate air pollution to its health impacts in Malaysia are limited. The lack of data gathering for environmental epidemiological analysis renders it difficult to estimate the health impacts of air pollution (Afroz, et al., 2003).

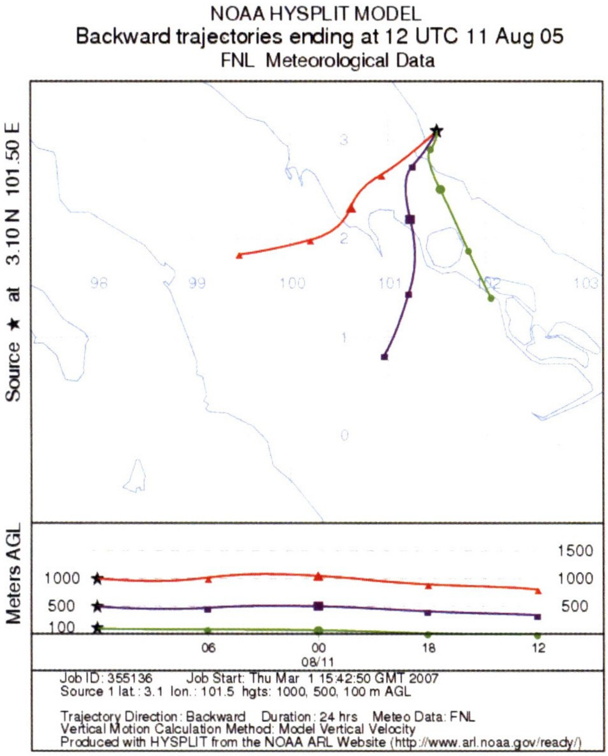


Figure 3.2 Backward air trajectories that originate from Sumatera arrive at Kuala Lumpur on 11 August, 2005

The API during the haze episode in August 2005 reached unhealthy levels for human health especially on the west coast of Peninsular Malaysia, which recorded the API value of more than 100. This value would trigger unhealthy symptoms to high risk patients with asthma and heart diseases (Table 3.1). The API value on 11 August 2005 recorded unhealthy levels which cautioned people to stay indoors.

The number of people who went to hospitals for upper respiratory infections (URTI) increased at the Malacca Hospital. At the Tengku

Ampuan Rahimah Hospital, both URTI and asthma patients had increased since June 2005 when the air quality conditions reached moderate levels. The highest number of patients was between August and September, when the haze condition was at its worst (Figures 3.3 and 3.4). Children below 12 years old were the most affected.

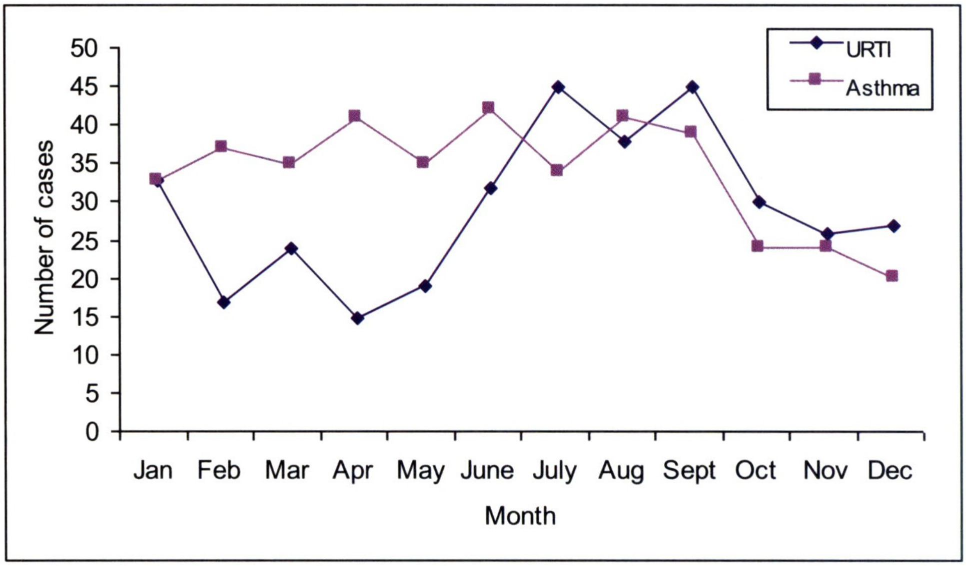


Figure 3.3 Number of patients treated for URTI and asthma at the Malacca Hospital

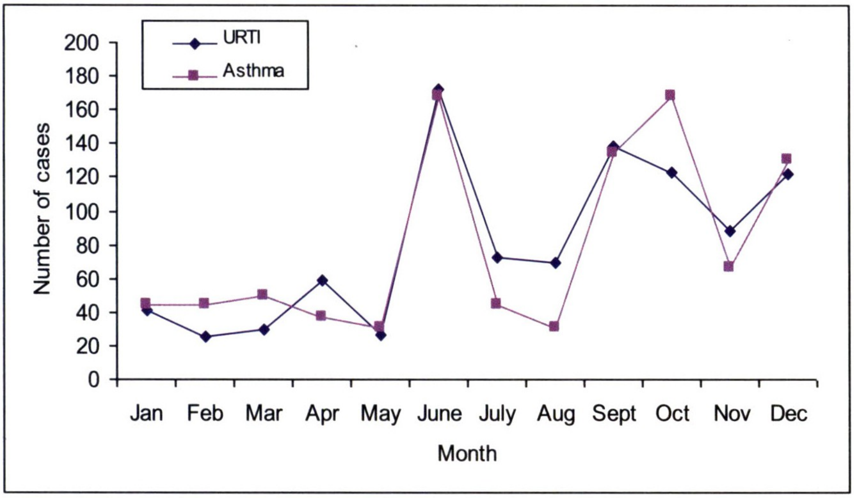


Figure 3.4 Number of patients treated for URTI and asthma at the Tengku Ampuan Rahimah

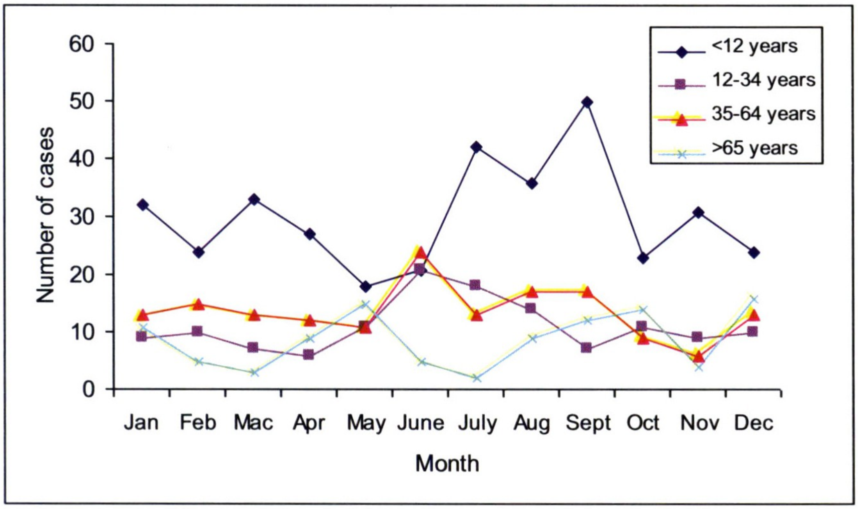


Figure 3.5 Number of patients treated for respiratory infections based on age groups at the Malacca Hospital

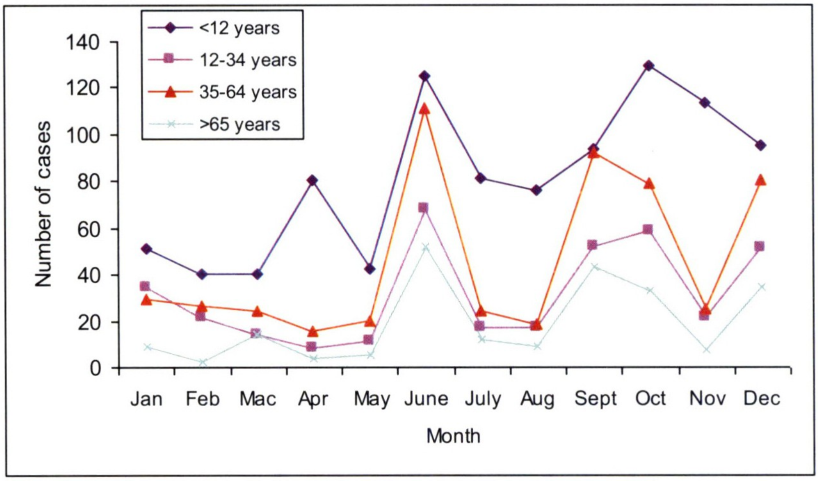


Figure 3.6 Number of patients treated for respiratory infections based on age groups at the Tengku Ampuan Rahimah Hospital

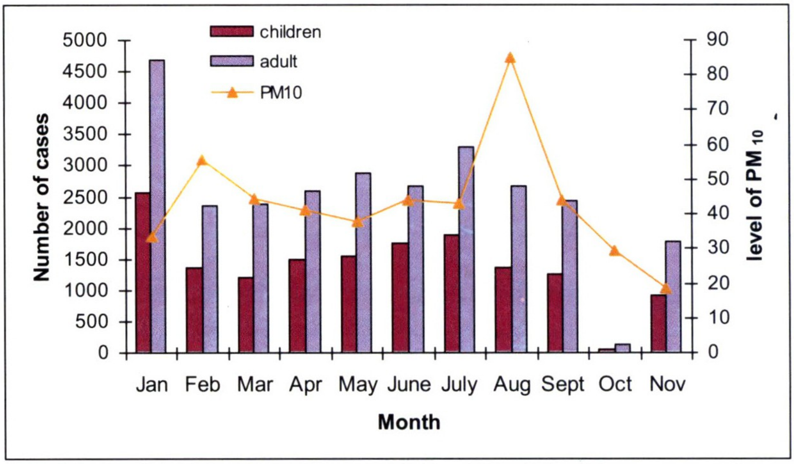


Figure 3.7 Relationship between the PM_{10} levels and URTI cases in adults and children recorded from Hospital Kuala Lumpur between January and November 2005

Figure 3.7 shows an increasing trend in the URTI cases among children and adults in relation to PM_{10} from February to July 2005 (with the exception of January) while the trend subsequently decreased until November 2005. This could be due to public awareness in response to the government's recommendation to avoid outdoor activities, remain indoors as much as possible, usage of air conditioning, and wearing of respiratory masks (Heil and Goldammer, 2001).

3.7 Conclusion

The 2005 smoke haze episode posed health risk to the public. In Malaysia, the API reached dangerous levels and was considered hazardous to public health. The extremely high values of PM_{10} over several cities in Peninsular Malaysia were caused by forest fires in Riau and South Sumatra due to land clearing for oil palm and timber plantations.

Even though the API recorded reached 500, the information from hospitals indicated only a small increase in patients seeking treatment for respiratory ailments. Lack of data for environmental epidemiological analysis makes it difficult to estimate the health impacts of haze pollution. The unrecorded data of patients seeking treatment from non-government facilities is also important to determine the impact of air pollution, especially during haze episode in the future.

Acknowledgments

We would like to express our sincere appreciation to the Record Unit of the Hospital Melaka, Hospital Kuala Lumpur, Hospital Tengku Ampuan Rahimah, Malaysian Meteorological Department and Universiti Kebangsaan Malaysia for contributing the monthly data of respiratory diseases, and daily PM_{10} data used in this study.

CHAPTER 4

Recent Trends of Air Quality Parameters in the Klang Valley: A Statistical Analysis

Abd Rahim Md Nor and Siti Nur Shazilla Zaki

4.1. Introduction

The Klang Valley is considered the fastest developing region in the country, experiencing the highest population growth during the last four decades, and is the nation's most densely populated area. With intense economic activities including especially air pollutant-producing activities in the transportation and industrial sectors, the Klang Valley is expected to demonstrate higher levels of air pollution relative to other regions nationwide. Sham (1976a, 1976b) is the pioneer climatologist who has contributed much knowledge to aspects of air quality properties in the Klang Valley region through many studies including the concentration patterns of certain air pollutants based on field data. He estimated air pollution emissions from fuel (Sham, 1979), analysed daily cycles of air pollution concentrations (Sham, 1984a) and calculated the concentrations of air quality parameters during weather hazards such as haze (Sham, 1984b). More recent studies on air pollution in the Klang Valley have dealt with the chemical analysis airborne particulates and atmospheric aerosols collected at sampling stations (Abas and Simoneit 1996; Abas et al. 2004; Yousef et al. 2006). Systematic collection of atmospheric time series data in the Klang Valley started much later than the pioneer works, with the first six permanent automatic monitoring stations for the region established in 1996 by the Department of Environment (DOE). A preliminary attempt to examine the time series data of transportation activity-related air pollutants in the region was reported by Abd Rahim Md Nor (2006) using a limited data covering a five-year period. The study reported in this section moved a step forward by incorporating air quality data covering a longer period from 1998 to 2005, and included the six monitoring stations to represent the region. In this work, the air quality issue was examined by looking at the trends in the levels of air quality parameters in the Klang Valley, using the DOE data.

4.2. Objectives of the chapter

The main objective of this chapter is to analyse the air quality data trends for the Klang Valley using simple statistical methods for each type of pollutants. In particular, the content of the chapter is fourfold. Firstly, to provide a brief introduction of each air pollutant, particularly explaining its common sources and adverse effects on human beings. Second, to determine the annual mean levels of the air quality parameters in the Klang Valley based on hourly readings at all monitoring stations for the 1998-2005 period. Third, to compare the levels of air pollution parameters among the monitoring stations which are many kilometres apart, located at different distances from the city centre and the sea, and having basically different land use types. Fourth, to examine the variability in the monthly levels of the air pollution parameters for each year of the study period.

4.3. Methodology

Currently, the Klang Valley has six air quality monitoring stations located in Gombak, Klang, Kuala Lumpur, Petaling Jaya, Shah Alam and Kajang, out of a total of 50 DOE monitoring stations at various locations throughout the country. Gombak was the first station set up in this region, commissioned by the DOE in April 1996, while the one located at Sekolah Menengah Victoria in Kuala Lumpur, was commissioned in November 1996. It was decommissioned in February 2004 and moved to a new location in Cheras (Table 4.1). At each station, hourly daily readings of the air quality and climate parameters were automatically recorded. The yearly average data, maximum and minimum values were calculated from monthly average readings of each monitoring station. However, the readings were incomplete from 1996 to 1998.

The data was subjected to statistical analysis using SPSS (Statistical Package for Social Scientists) version 14 to obtain descriptive statistics, to establish annual trends, and to draw box plots for each pollutant type to show the monthly variabilities of the pollution levels for each year, such as range, median, maximum, minimum and inter-quartile ranges. Graphics of monthly outliers and extreme values from the twelve-month analysis in each year are obtained. Trend lines are fitted for linear, logarithmic, polynomial, power and exponential curves to find the best fit selected from highest coefficient of determination. Data for this study only considered five air pollution parameters, carbon monoxide (ppm), ozone (ppm), particulate matter of less than 10 micron (μg/m^3), nitrogen dioxide (ppm), and sulphur dioxide (ppm), in line with the national annual air quality reports published for the country (Department of Statistics, 2003).

Table 4.1 DOE Monitoring Stations in the Klang Valley

Site ID	Location	Latitude	Longitude	Commissioning Date
CAC 005	Jab. Bekalan Air Daerah Gombak	3° 15.702′N	101° 39.103′E	12 April 1996
CAC 011	S.M.(P) Raja Zarina, Klang	3° 0.620′N	101° 24.484′E	7 March 1997
CAC 012	S.M. Victoria, Kuala Lumpur	3° 8.286′N	101° 42.274′E	25 November 1996
CAC 016	Sek. K. Sri Petaling, Petaling Jaya	3° 6.612′N	101° 42.274′E	12 December 1996
CAC 023	Country Heights, Kajang	2° 59.645′N	101° 44.417′E	18 June 1997
CAC 025	Sekolah TTDI Jaya, Shah Alam	3° 6.287′N	101° 33.368′E	18 June 1997
CAC 054	S.M.Keb. Seri Permaisuri, Cheras	3° 6.376′N	101° 43.072′E	20 February 2004

Note: Station CAC012 was decommissioned on 19 February 2004 and moved to a new station in Cheras.

4.4. Descriptive Statistics of the Levels of Air Quality Parameters

4.4.1. Carbon Monoxide

A colourless, odourless and tasteless gas, carbon monoxide (CO) is the product of the incomplete combustion of carbon-containing compounds, notably in internal-combustion engines. This substance is a toxic gas, which impedes the oxygen carrying capacity of hemoglobin in the body. Anthropogenic CO from automobile and industrial emissions may contribute to the greenhouse effect and global warming. In urban areas, CO along with aldehydes, reacts photochemically to produce peroxy radicals.

The latter react with nitrogen oxide (NO) to increase the ratio of nitrogen dioxide (NO_2) to nitrous oxide (N_2O), which reduces the quantity of NO that is available to react with ozone (O_3). CO is also a significant constituent of smoke.

The average readings at the five monitoring stations in the Klang Valley showed that during the 1998-2005 period, CO levels were relatively stable, ranging from 1.18 ppm in 1998 to 0.99 ppm in 2005, and lower than the 9 ppm critical level stipulated by the DOE (Department of Statistics, 2003). In general, the Kuala Lumpur station recorded the highest figures, ranging from 2.3 ppm in 1998 to 1.04 in 2005. Kajang, which recorded the lowest level of all stations, showed very stable figures of less than 1 ppm during the study period. Relative to other stations, Kuala Lumpur demonstrated more significant changes throughout the years, with CO levels reaching the highest level at 2.74 ppm in 2000, and stabilising at 2.5 ppm for several years before descending to 1.4 ppm and 1.0 ppm in 2004 and 2005, respectively (Figure 4.1). The sudden drop towards the end of the study period could have been associated with the decommissioning of the station at Sekolah Menengah Victoria. Overall, Klang station recorded the second highest CO levels, maintaining at approximately 1.2 ppm throughout the study period.

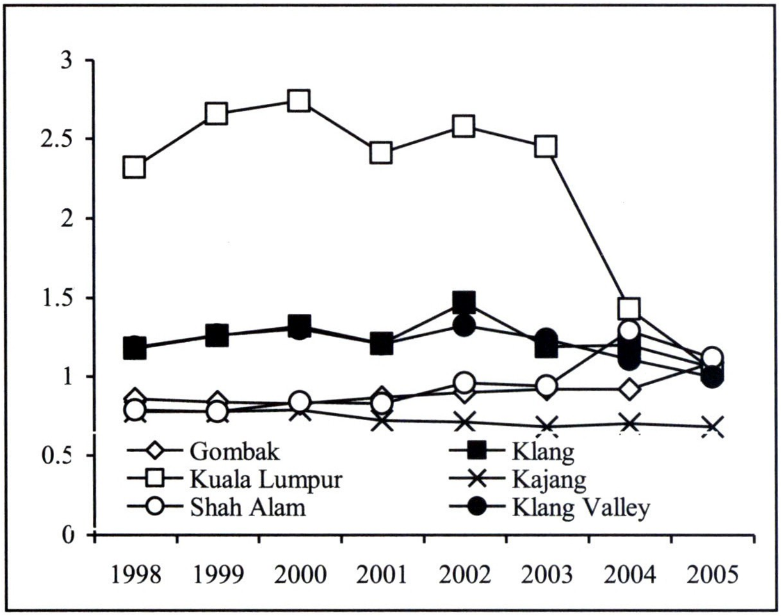


Figure 4.1 Carbon monoxide (ppm) trends for the period 1998-2005

4.4.2. Nitrogen Dioxide

Nitrogen dioxide (NO_2) is a reddish-brown gas with a pungent and irritating odour. It transforms in the air to form gaseous nitric acid and toxic organic nitrates. This pollutant also plays a major role in atmospheric reactions that produce ground-level ozone, a major component of smog. It is also a precursor to nitrates, which contribute to increased aerosols in the atmosphere. All combustion in air produces oxides of nitrogen (NO_x), of which NO_2 is a major product. In most cities, motorised vehicles are the main sources of this gas, while other sources are power generators, incinerators, primary metal processing, and natural sources such as lightning and aerobic activities of soil bacteria. NOx can irritate the lungs and lower resistance to respiratory infection, especially to sufferers of asthma and bronchitis. NOx chemically transforms into nitric acid and, when deposited, contributes to lake acidification, corrode metals, fade fabrics and degrade rubber. It can also damage trees and crops, resulting in substantial economic losses.

The time series data show that the Klang Valley has relatively stable levels of NOx, at 0.021 ppm both at the beginning and end of the study period, much lower than the critical level of 0.17 ppm set by the DOE Ambient Air Quality Guidelines. Kuala Lumpur again recorded the highest NOx reading among the six monitoring stations, while Kajang still record lowest. The gaps between the highest and lowest readings were quite small throughout the period, especially during the last five years of the millennium. Levels of this pollutant showed significant peaks in 1999 for three of the monitoring stations, the highest being Kuala Lumpur at 0.073 ppm.

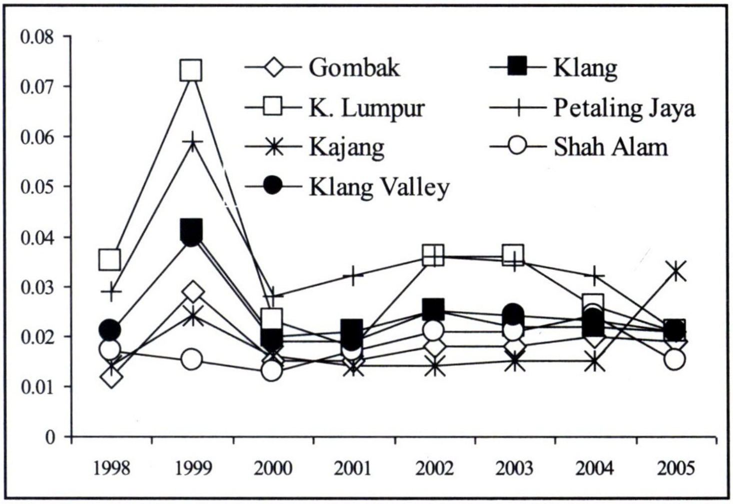


Figure 4.2 Nitrogen dioxide (ppm) trends for the period 1998-2005

4.4.3. Ozone

A triatomic molecule, consisting of three oxygen atoms, Ozone (O_3) is an allotrope of oxygen that is much less stable than the diatomic species, Oxygen (O_2). It is not emitted directly by motorised vehicles' engines or by industrial operations but formed by the reaction of sunlight on air containing hydrocarbons and nitrogen oxides that react to form ozone directly at the source of the pollution or many kilometers down wind. Low level ozone (or tropospheric ozone) is regarded as a pollutant by the World Health Organisation. Ground-level ozone is an air pollutant with harmful effects on the human respiratory system. Ozone present in the upper troposphere acts as a greenhouse gas, absorbing some of the infrared energy emitted by the earth. High concentrations of ozone, created by high concentrations of pollution and daylight UV rays at the earth's surface, can harm lung function and irritate the respiratory system. There has also been shown to be a connection between increased ozone caused by thunderstorms and hospital admissions of asthma sufferers. As well as having an impact on human health, there is also evidence of significant reduction in agricultural yields due to increased ground-level ozone and pollution which interferes with photosynthesis and stunts overall growth of some plant species.

The data shows that Klang Valley has levels of ozone lower than the 0.100 ppm set by the national guideline, at between 0.043 ppm in 1999 to 0.060 ppm in 2005, with a minimum of 0.027 in year 2000 (Figure 4.3). The highest levels were not in Kuala Lumpur as the city centre showed lower levels of ozone than several other stations especially during the earlier years of the period under study, and in fact the lowest for 2000. Instead, Kajang demonstrated relatively higher levels compared with other locations, ranging from 0.061 ppm in 1999 to 0.067 in 2005, and had even reached as high as 0.078 in 2000, the highest of all stations. In fact, the 2000 readings showed the odd position of Kajang, a medium-sized city at the southeast fringe of Klang Valley, which recorded the highest not only for its own but also for the region as a whole, while other stations experienced the lowest levels of ozone. Klang, another medium-sized city but with population density higher than Kajang, recorded the lowest ozone levels for the whole period examined.

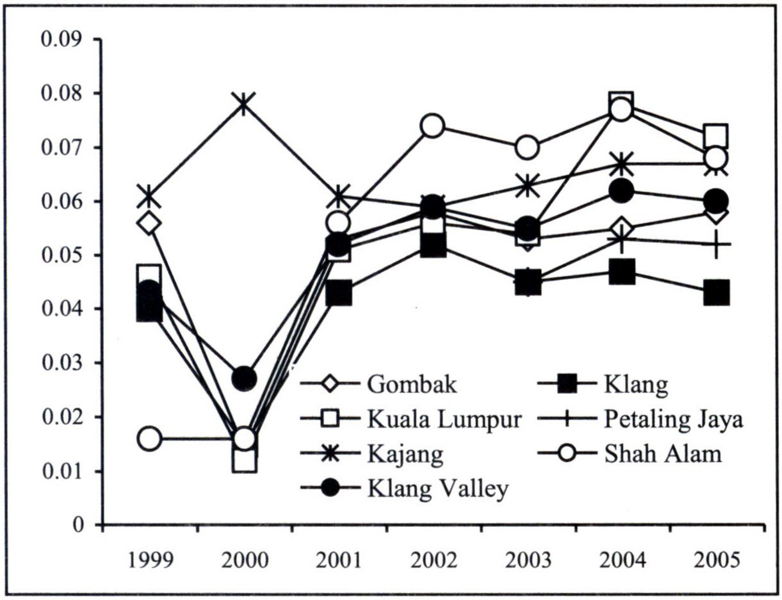


Figure 4.3 Ozone (ppm) trends for the period 1999-2005

4.4.4. Particulate Matter

Airborne particulate matters of less than 10 micron (PM_{10}) consist of many different substances suspended in air in the form of particles (solids or liquid droplets) that vary widely in size. These particles, which include both fine and coarse dust particles, pose a serious health concern because they can pass through the nose and throat and get into the lungs. Particles larger than 10 micron in diameter that are suspended in the air are referred to as total suspended particulates (TSP). These larger particles can cause irritation to the eyes, nose and throat in some people, but they are not likely to cause more serious problems since they do not get down into the lungs. Dust and smoke may irritate healthy people's eyes, nose, throat, and lungs, and might cause more serious problems in sensitive populations. Certain sensitive populations, such as individuals with asthma and other respiratory diseases, those with cardiovascular disease, children and the elderly, are susceptible to more serious symptoms, including cough, phlegm, wheezing, shortness of breath, bronchitis, increased asthma attacks, and aggravation of lung or heart disease. Exposure to fine particles (e.g. smoke) is of particular concern, and can be associated with several serious health effects. Some sensitive people might experience health problems after even short exposures to fine particles, such as for several hours or a day.

In general, the Klang Valley experienced between 48.5 $\mu g/m^3$ and 68.7 $\mu g/m^3$ levels of PM_{10} during the 1998-2005 period, approximately one-third the maximum level set by the Recommended Malaysian Ambient Air Quality Guideline of 150 $\mu g/m^3$ (Figure 4.4). Overall, the highest levels were mostly observed at the Kuala Lumpur monitoring stations located at Sekolah

Menengah Victoria which was later moved to Sekolah Menengah Seri Permaisuri in Cheras. However, the highest peak during the period under study belonged not to Kuala Lumpur but to Klang, which recorded 89.5 μg/m^3 in 2002. The first few years saw Shah Alam demonstrating the lowest levels of PM_{10} for this region, but this was superseded by Kajang starting from 2002, after having an equal reading with Shah Alam the year before.

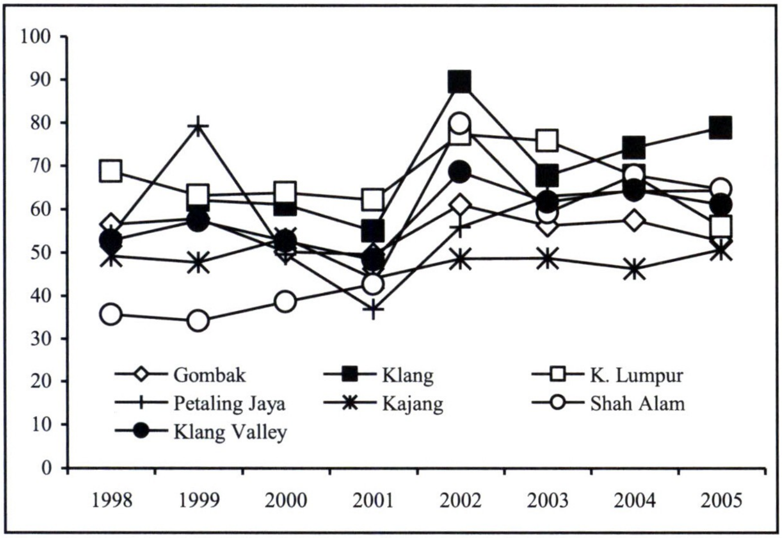


Figure 4.4 Particulate matter, PM_{10} (μg/m^3) trends for the period 1998-2005

4.4.5. Sulphur Dioxide

Colourless and smells like burnt matches, sulphur dioxide (SO_2) is the main product from the combustion of sulfur compounds and is of significant environmental concern. Volcanoes are the natural source of sulphur dioxide, but various industrial processes are the principal man-made culprit. Since coal and petroleum contain various amounts of sulfur compounds, their combustion in power generating plants, industrial processes, and motor vehicles, generates sulfur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain. This gas can be oxidised to sulphur trioxide, which in the presence of water vapour is readily transformed to sulphuric acid mist. SO_2 is a precursor to sulphates, which are one of the main components of respirable particles in the atmosphere. The presences of this pollutant in the atmosphere originate from smelters and utilities, especially electrical generation. Other industrial sources include iron and steel mills, petroleum refineries, and pulp and paper mills, while small sources include residential, commercial and industrial space heating. Health effects caused by exposure to high levels of SO_2 include breathing problems, respiratory illness, changes in the lung's defenses, and worsening respiratory and cardiovascular disease with effects being the most serious among people with asthma or chronic lung or heart disease. It also damages trees and crops. SO_2, along with nitrogen oxides, are the main precursors of acid rain, which contributes to the acidification of lakes and streams, accelerated corrosion of buildings and reduced visibility. SO_2 also causes the formation of microscopic acid aerosols, which have serious health implications as well as contributing to climate change.

The levels of sulphur dioxide in Klang Valley as represented by the six monitoring stations show a maximum of 0.0088 ppm recorded in the first year, and a minimum of 0.004 ppm in the final year of the study period. The line that represents the CO_2 levels for this region is located approximately in the middle among all the monitoring stations (Figure 4.5), and this is quite consistent and true for the whole period, implying that its relative distances with the pollutant's levels for individual stations are quite stable during the period under study. In general, relatively high levels of sulphur dioxide pollution were recorded in Klang, with five of the total eight years having the highest levels of sulphur dioxide relative to other stations in the region. However, the highest levels were recorded in stations in the industrial city of Petaling Jaya and, to a lesser extent, the capital state city of Shah Alam, two mature cities in the region, and this was especially true for the first two years of the study period. Gombak, an increasingly densely populated residential area, has the lowest level of sulphur dioxide of not more than 0.0035 ppm throughout the 1998-2005 periods.

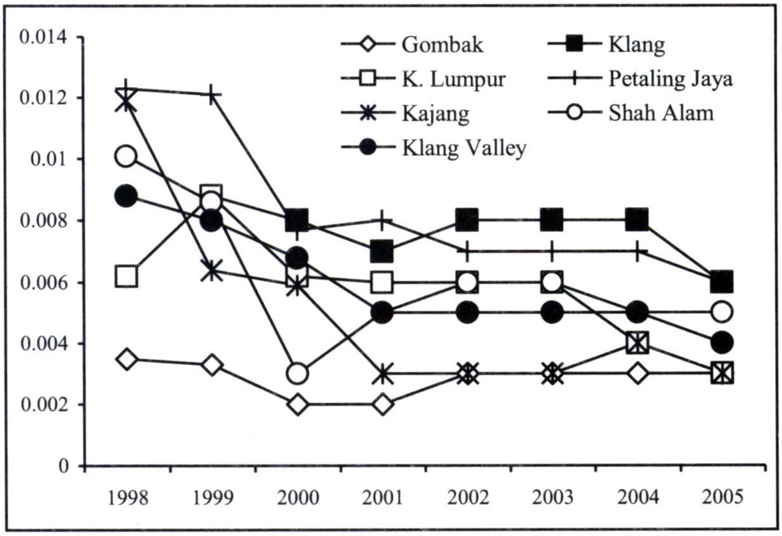


Figure 4.5 Sulphur dioxide (ppm) trends for the period 1998-2005

4.5. Statistical Analysis of Air Quality Parameter Trends

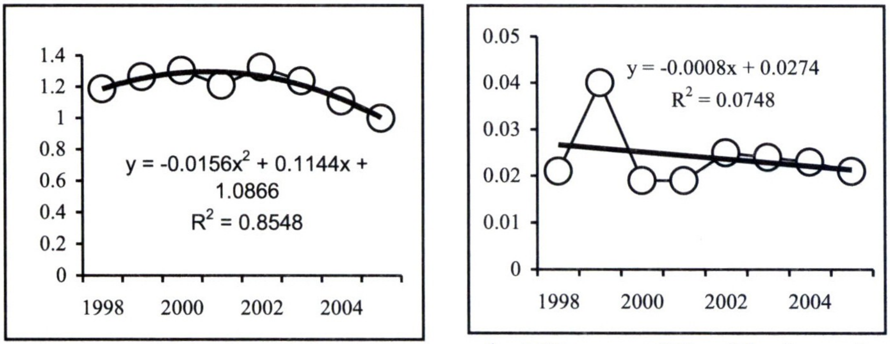
The eight-year period trend analysis of the carbon monoxide for the Klang Valley shows a slightly declining trend (Figure 4.6a). It was found that the polynomial was the most appropriate method of fitting the trend line, with a strong coefficient of determination (R^2) of about 0.85. Based on this historical data finding, the region is expected to experience lower levels of carbon monoxide in the next few years, but may demonstrate an increasing trend in the long run, although the increase will not be steep.

The general trend of nitrogen dioxide levels in the region shows a relatively huge fluctuation in the early part of the period under study, but became more stable in later years. Based on this historical data, the level of this pollutant is expected to experience a declining trend in the near future and in the long run, but this is an extremely unreliable prediction as shown by the small coefficient of determination derived (Figure 4.6b). Linear regression was the best method of fitting the time series data, resulting in an extremely small coefficient of determination, indicating that time, as against other factors, might not be the best determinant in explaining the trend of nitrogen monoxide in the region.

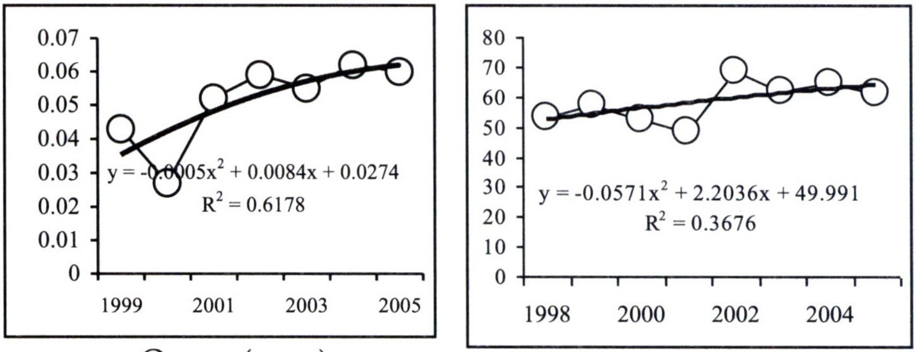
As for ozone, the data for the Klang Valley as a whole shows a quite clear indication of rising trend for the last eight years, beginning 1998 (Figure 4.6c). Polynomial method was the best way of fitting the trend line, yielding a relatively reliable trend with a goodness of fit of 0.6178, indicating that time contributed about 62 per cent in explaining the trend. It is quite clear that this region will be facing increasing levels of ozone in the immediate years to come as well as in the long run. Although ozone is particularly unstable in the atmosphere and has high hourly, daily and monthly variability, this prediction is considered reliable, bearing in mind that the source of this data in this study is the hourly records of the pollutant gathered from six stations of various locations for an eight-year period.

Particulate matter of less than ten micron (PM_{10}) shows a slight increasing trend for the region (Figure 4.6d). Linear and polynomial methods were found to be equally appropriate in fitting the trend line, yielding extremely similar coefficient of determinations of around 0.37. Although our calculation shows that the increase in particulate matter levels in the region is expected to happen not only in the years immediately after 2005 but also to sustain a relatively long period in the future, the gradients of the equations indicate that the increase will be small, and time might not be the most powerful determinant of the trend.

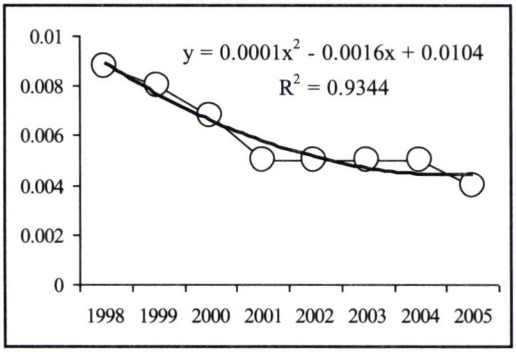
Finally, the sulphur dioxide levels in the region showed a convincingly declining trend for the past eight years with a slight fluctuation between year 2000 and 2003 (Figure 4.6e). Polynomial method was the best way of fitting the trend line, although both natural logarithmic and least square methods were equally appropriate, yielding coefficients of 0.9344, 0.9252 and 0.8483 respectively. Time was found to be remarkably able to explain the trend with accuracy levels of approximately 93 per cent based on the best method. Regardless of the methods used, this study is pretty sure that, *citrus paribus*, levels of this pollutant (SO_2) in the Klang Valley region is predicted to decline gradually, and this will be sustained for a long period in the future.



a. Carbon Monoxide (ppm) **b.** Nitrogen Dioxide (ppm)



c. Ozone (ppm) **d.** Particulate Matters (μg/m³)



e. Sulphur Dioxide (ppm)

Figure 4.6 Eight-year trends of each air quality parameters in Klang Valley

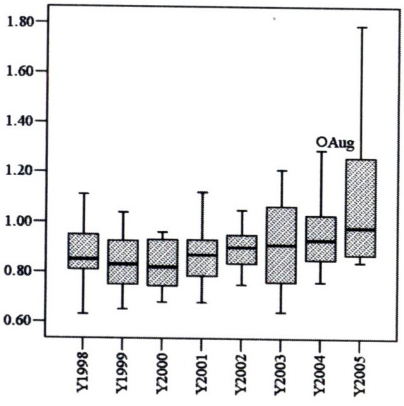
4.6. Monthly Variability of Carbon Monoxide

Several factors such as wind speed and direction, relief of the area, land use and levels of anthropogenic activities exert influences on the monthly variability in the carbon monoxide emission and distribution in the atmosphere. Examinations on the times series data of air quality parameters in the Klang Valley region reveal the presence of these influences as reflected in the variability of the concentration of the pollutants. As an illustration, this study examined this phenomenon using carbon monoxide as an example, a pollutant associated with motorised vehicles activities. Boxplot analysis, a method of graphic display of variabilities, outliers and extreme values was used in this study (Sincich, 1993; Hairs et al. 1995).

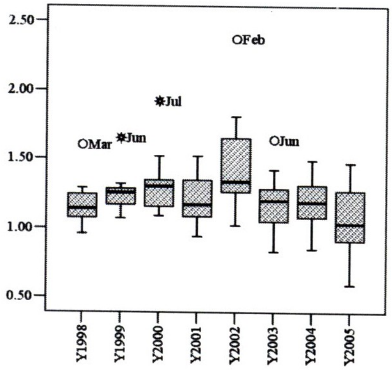
The data for Gombak shows that monthly variations in the levels of carbon monoxide (ppm) were quite low in the earlier parts of the period under study, but gradually increased towards the end, when the range for the carbon monoxide values reached the highest (Figure 4.7a). For this monitoring station, an outlier was detected for the month of August. Data gathered at the monitoring station in Klang demonstrates a relatively small monthly variation for most of the years under study with a small exception of 2002. However, the box plot analysis revealed that more than half of the years showed either outliers or extreme values of carbon monoxide pollutant namely in March for 1998, June in 1999, July in 2000, February for 2002 and June again for 2003 (Figure 4.7b). The location of Klang near the sea could have influenced this variability. Data from the Kuala Lumpur station showed a clear variation in the first half of the study period with relatively high ranges for each year and an outlier in October 2000. However, a significant decline of CO levels occurred during the second half of the study period, indicating smaller ranges, which also coincided with the decline in the annual average levels. The Kuala Lumpur data displayed outliers and extreme values lower than average compared to other stations as shown for the 2000, 2002 and 2003 in October, January and October, respectively.

For Kajang, despite its relatively low levels of carbon monoxide, monthly variations were found to be a rule rather than an exception (Figure 4.7d). Similar to Gombak, the deviations from the mean were relatively greater in the earlier years, but decreased somewhat in the middle, before widening in the later years. Shah Alam also shows a relatively even distribution of monthly emission of carbon monoxide pollutant in its atmosphere throughout the eight-year records (Figure 4.7e). This happened despite the fact that the overall level of carbon monoxide in this city shows an increasing trend. An outlier was detected in August in 2003 with a value of lower than the mean, indicating the lowest emission of the whole month in the year. Another outlier, with a value greater than the average, was detected for April in year 2005.

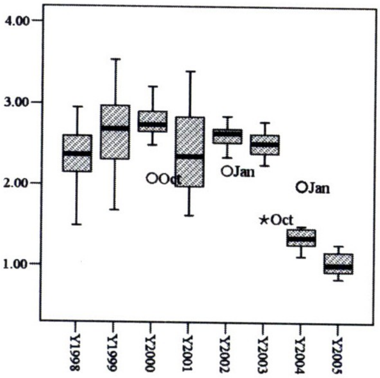
Combining all the five monitoring stations to represent the whole Klang Valley (Figure 4.7f), the variability of monthly emission of carbon monoxide for the years under study was relatively similar, with only two outliers each in July 2000 with values higher than median, which was balanced by another outlier higher than the median in October 2003. There was also a declining trend in the annual average levels of this pollutant in the Klang Valley for the period under study.



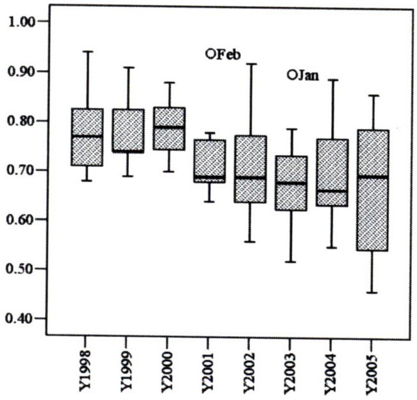
a. Gombak



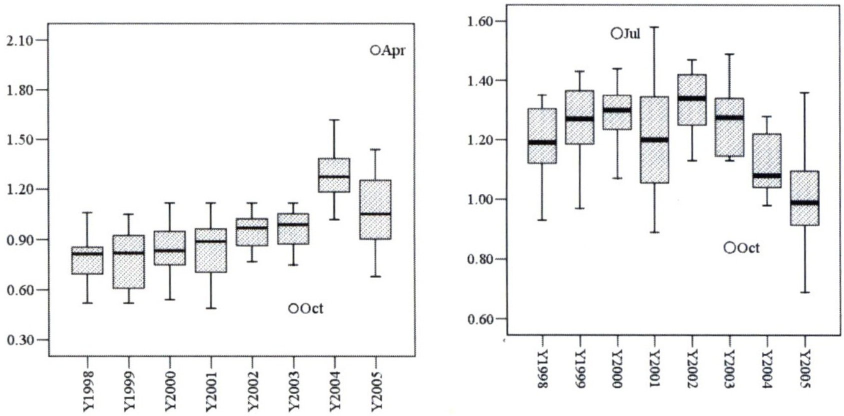
b. Klang



c. Kuala Lumpur



d. Kajang



e. Shah Alam

f. All Stations (Klang Valley)

Figure 4.7 Monthly variability of carbon monoxide (CO_2) by monitoring stations

4.7. Conclusion

The descriptive statistic analysis using the daily average of the readings from the five monitoring stations to represent the region shows that during the 1998-2005 periods the Klang Valley experienced relatively stable levels of carbon monoxide, ranging from 1.18 ppm in 1998 to 0.99 ppm in 2005, much lower than the critical level for the nation. The time series data also shows that this region has relatively stable levels of nitrogen dioxide, at 0.021 ppm both at the beginning and end years of the study period, much lower than the critical level of 0.17 ppm set by the national standard. The data shows that this region had levels of ozone lower than the 0.100 ppm set by the national guideline, at between 0.043 ppm in 1999 to 0.060 ppm in 2005, with a minimum of 0.027 in 2000. In general, it experienced between 48.5 μg/m³ and 68.7 μg/m³ level of PM_{10} during the 1998-2005 period, approximately one-third the maximum level set by the national guideline of less than 150 μg/m³. The levels of sulphur dioxide as represented by the six monitoring stations show a maximum of 0.0088 ppm recorded in the first year, and a minimum of 0.004 ppm in the final year of the study period. In general, the overall level of this pollutant for the region is approximately somewhere in the middle among all the monitoring stations, and this is quite consistent and true for the whole study period.

The eight-year period trend analysis on the air quality parameters strongly shows that the region is expected to experience a slight decline in carbon monoxide levels in the future. As similar trend is expected to occur in the near future and in the long run for nitrogen dioxide, but this prediction is rather weak. For ozone, historical data indicates that this pollutant is expected to be on the increase in the immediate years to come as well as in the long run. For particulate matter of less than ten micron, the trend analysis indicates it will be increasing, not only in the years immediately after 2005 but also to sustain a relatively long period in the future, although the increase will be small, and time might not be the most powerful determinant of the trend. Sulphur dioxide levels in the region showed a convincingly declining trend for the past eight years with a slight fluctuation in the mid years, and it is strongly predicted that levels of this pollutant in the Klang Valley region will decline gradually, and this will be sustained for a long period in the future.

Finally, analysis of carbon monoxide levels by combining all the six monitoring stations to represent the whole Klang Valley, shows that there are indications that generally the variability of monthly emission of this pollutant was relatively similar for each year. There was also a clearly declining trend in the annual average levels of this pollutant in Klang Valley for the period under study.

CHAPTER 5

Spatial Distribution of the August 2005 Haze in the Klang Valley, Peninsular Malaysia, Using Digital Elevation Model

Khairul Nizam Abdul Maulud
Abd Rahim Md Nor
Halmy Sirat

5.1. Introduction

The phenomenon of haze is defined by the Malaysian Meteorological Services as the presence of fine particles of size 0.1 to 1.0 µm in diameter, dispersed at a high concentration in the atmosphere. Horizontal visibility is diminished, giving the atmosphere a characteristic opalescent appearance (Soleiman et al., 2003). Airborne particles of tiny sizes during haze episodes are of concern because of their harmful effects on health and adverse impacts on the environment. Particulate matter of less than 10 µm (PM_{10}) can also have undesirable impacts on meteorological processes in terms of reducing visibility and solar radiation, which can trigger chemical reactions in the atmosphere, producing harmful secondary pollutants. In the Klang Valley of Selangor, Peninsular Malaysia, the first unusually thick haze which attracted public attention and was widely reported in the local media, occurred in September 1982 (Sham, 1984). Other major haze episodes lasting for varying periods of times occurred in April 1983, August 1990, June 1991, October 1991, August to October 1994, and August to October 1997, respectively.

The August 2005 haze hazard in Malaysia was a week-long choking smog event that almost brought the Klang Valley in the central western coast of the Peninsular Malaysia to a standstill. At its worst level on 11 August 2005, the air quality in the capital city of Kuala Lumpur was so poor that health officials advised citizens to stay at home with doors closed. Some schools were closed to keep children from being exposed to the haze. On the same day, a state of emergency was announced for the Port Klang area and the neighbouring district of Kuala Selangor, after the Malaysian Air Pollution Index (MAPI) reached dangerous levels. This was the first time that a state of emergency was imposed in Malaysia since the September 1997 haze, when Sarawak was placed under a state of emergency due to similar reasons.

The main objective of this chapter is to analyse the August 2005 haze data in the Klang Valley by utilizing the Inverse Distance Weighted (IDW) techniques of Geograpical Information System (GIS) for interpolation the air pollution parameters.

5.2. GIS Application in Haze Analysis

GIS is a computer system that stores and links geographically referenced data with graphic map features to allow a wide range of information processing, display operations, map production, analysis, and modelling (Antenucci et. al., 1991). A digital base map can be overlaid with data or other layers of information onto a map in order to view spatial information and relationships. Information about features on maps such as coordinate, location and address can be viewed in databases behind the map. The GIS application in this study is used to interpret spatial dispersion and distribution of airborne particulates over the Klang Valley during the August

2005 haze, using spatial element as a medium of visualisation. The technique used was the IDW, which allowed the haze managers to visualise and understand physical features and the relationships that influence haze behaviour.

5.3. The Study Area

The Klang Valley is the fastest developing region in the country, having the highest population growth during the last four decades. Intensive economic activities, especially in the transportation and industrial sectors, have contributed towards the high levels of urban air pollution in the area (Figure 5.1). The Selangor state has six air quality recording stations set up by the Department of the Environment (DOE) located in Gombak, Klang, Kuala Lumpur, Petaling Jaya, Shah Alam and Kajang, and two neighbouring stations in Putrajaya and Kuala Selangor. The location and characteristics of each monitoring station are shown in Table 5.1, and Figure 5.2. At each station, automatic hourly readings of the air quality and climate parameters are recorded daily.

Table 5.1 Details of Observation Stations in the Klang Valley

Station Code	Observation Station	Location	Parameters	Latitude	Longitude
CA0005	Jabatan Bekalan Air Daerah Gombak	Gombak	PM_{10}, NO_2, SO_2, O_3, CO	03º 15.702′ N	101º 39.103′ E
CA0011	Sek. Men. Perempuan Raja Zarina	Klang	PM_{10}, NO_2, SO_2, O_3, CO	03º 00.620′ N	101º 24.484′ E
CA0016	Sek.Ren.Sri Petaling	Petaling Jaya	PM_{10}, NO_2, SO_2, O_3, CO	03º 06.612′ N	101º 42.274′ E
CA0023	Country Heights, Kajang	Kajang	PM_{10}, NO_2, SO_2, O_3, CO	02º 59.645′ N	101º 44.417′ E
CA0025	Sek. Ren. Keb. TTDI Jaya	Shah Alam	PM_{10}, NO_2, SO_2, O_3, CO	03º 06.287′ N	101º 33.368′ E
CA0048	Sek. Men. Sains Kuala Selangor	Kuala Selangor	PM_{10}	03º 19.592′ N	101º 15.532′ E
CA0054	Sek. Men. Keb. Sri Permasuri	Cheras	PM_{10}, NO_2, SO_2, O_3, CO	03º 06.376′ N	101º 43.072′ E
CA0053	C4, Parcel C, Putrajaya	Putrajaya	PM_{10}, NO_2, SO_2, O_3, CO	02º 56.078′ N	101º 42.004′ E

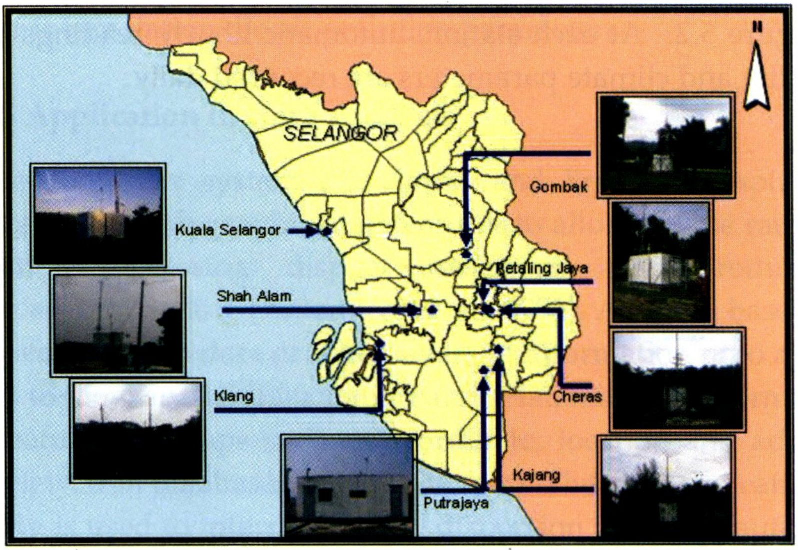


Figure 5.1 Locations of the air quality monitoring stations

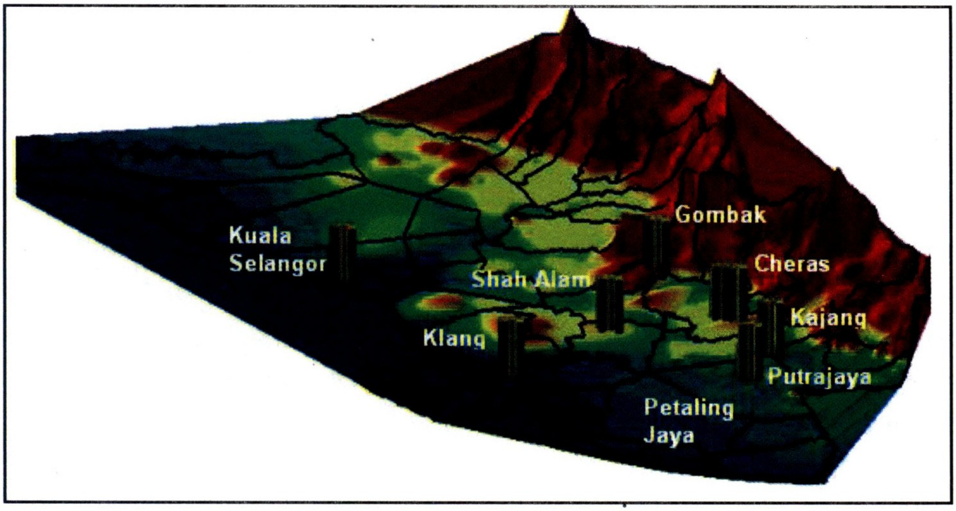


Figure 5.2 Three-dimensional view of relief of the study area

5.4. Methodology

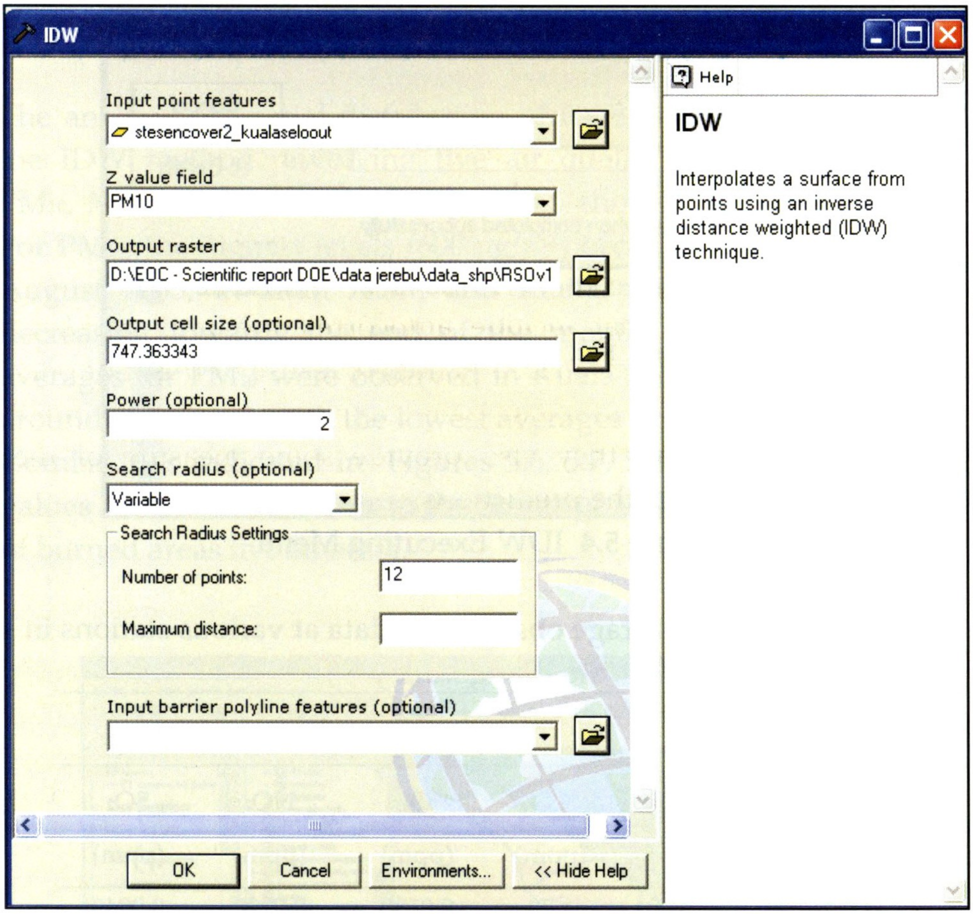
Surface interpolation functions create a continuous (or prediction) surface from sampled point values. The continuous surface representation of a raster dataset represents height, concentration, or magnitude of the phenomenon, for example, air quality, elevation, pollution, or noise. In the present study, air quality parameters such as PM_{10}, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3) and carbon monoxide (CO) are analysed. The average levels of each of the pollutants are presented in Table 5.2.

Surface interpolation functions make predictions from sample measurements for all locations in a raster dataset. There are several ways to derive a prediction for each location. With each model, there are different assumptions made of the data, and certain models are more applicable for specific data with predictions based on different calculations.

The IDW and Spline methods are referred to as deterministic interpolation methods because they assign values to locations based on the surrounding measured values and specified mathematical formulas that determine the smoothness of the resulting surface. A second family of interpolation methods consists of geostatistical methods, such as Kriging, which is based on statistical models that include autocorrelation (the statistical relationship among the measured points). Because of this, not only do geostatistical techniques have the capability of producing a prediction surface, but they also provide some measure of the certainty or accuracy of the predictions.

The interpolation tools are generally divided into deterministic and geostatistical methods. Topo to Raster and Topo to Raster by File are interpolation methods designed for creating continuous surfaces from contour lines; contain properties favourable for creating surfaces for thematic analysis. The available interpolation tools can work in ArcToolbox, Map Algebra, or ArcObjects. The following are steps involved in the IDW analysis (Figures 5.3 and 5.4):

1) Select the Spatial Analyst Tools – Interpolation – IDW;
2) Fill in the input point features and Z value field to identify the parameter (CO, O_3, PM_{10}, SO_2 and NO_2);
3) Click OK;
4) Wait for IDW processing;
5) Examine and analyse the results.



Input point features: stesencover2_kualaseloout

Z value field: PM10

Output raster: D:\EOC - Scientific report DOE\data jerebu\data_shp\RSOv1

Output cell size (optional): 747.363343

Power (optional): 2

Search radius (optional): Variable

Search Radius Settings

Number of points: 12

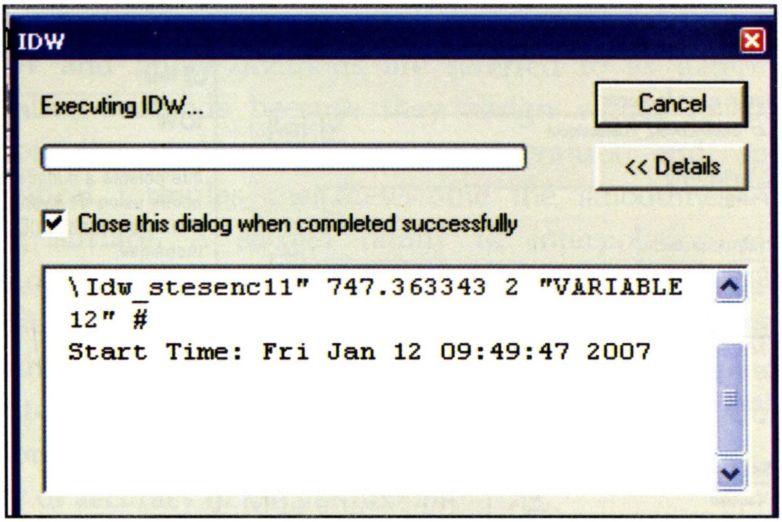
Maximum distance:

Input barrier polyline features (optional):

IDW

Interpolates a surface from points using an inverse distance weighted (IDW) technique.

Figure 5.3 IDW Analysis Menu



Executing IDW...

☑ Close this dialog when completed successfully

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\Idw_stesencl1" 747.363343 2 "VARIABLE
12" #
Start Time: Fri Jan 12 09:49:47 2007
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Figure 5.4 IDW Executing Menu

Table 5.2 Monthly average observation data at various stations in the Klang Valley

Station CODE	Air pollutants				
	PM_{10} (µg/m^3)	CO (ppm)	O_3 (ppm)	NO_2 (ppm)	SO_2 (ppm)
CA0005	73.00	1.79	0.0180	0.0220	0.0040
CA0011	105.00	1.44	0.0140	0.0190	0.0050
CA0016	90.00	2.25	0.0130	0.0330	0.0060
CA0023	68.00	0.86	0.0200	0.0150	0.0020
CA0025	90.00	1.44	0.0190	0.0210	0.0050
CA0048	97.00	0.00	0.0000	0.0000	0.0000
CA0054	84.00	1.26	0.0180	0.0200	0.0030
CA0053	85.00	2.09	0.0280	0.0120	0.0020

5.5. Results

The analysis of spatial distribution of haze was carried out using the IDW method, involving five air quality parameters namely PM_{10}, NO_2, SO_2, O_3 and CO. Figure 5.5 shows the interface result. For PM_{10}, the highest levels (600 μg/m³) occurred between 10 to 12 August 2005, in Shah Alam and Klang, with values gradually decreasing towards the end of the month. The relatively high averages for PM_{10} were observed in Kuala Selangor and Klang, at around 100 μg/m³, with the lowest averages occuring in Kajang and Gombak. As indicated in Figures 5.6, 5.7, 5.8 and 5.9, the highest values tend to occur closer to the Straits of Malacca, and the source of burned areas in Sumatera.

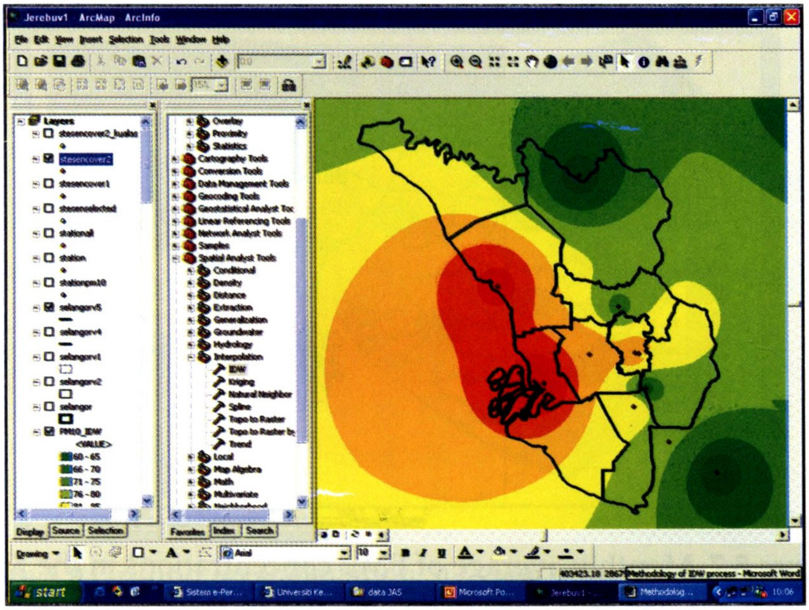

Figure 5.5 Interface results for PM_{10} in the Klang Valley

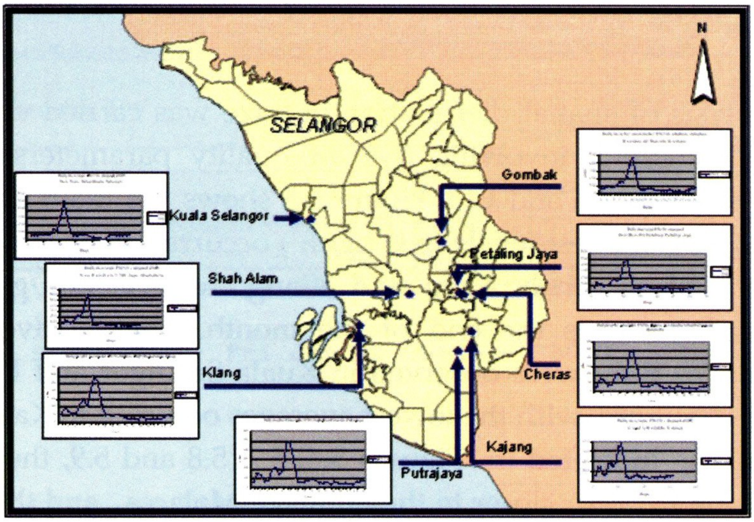

Figure 5.6 Daily Average of PM_{10} concentrations in the Klang Valley

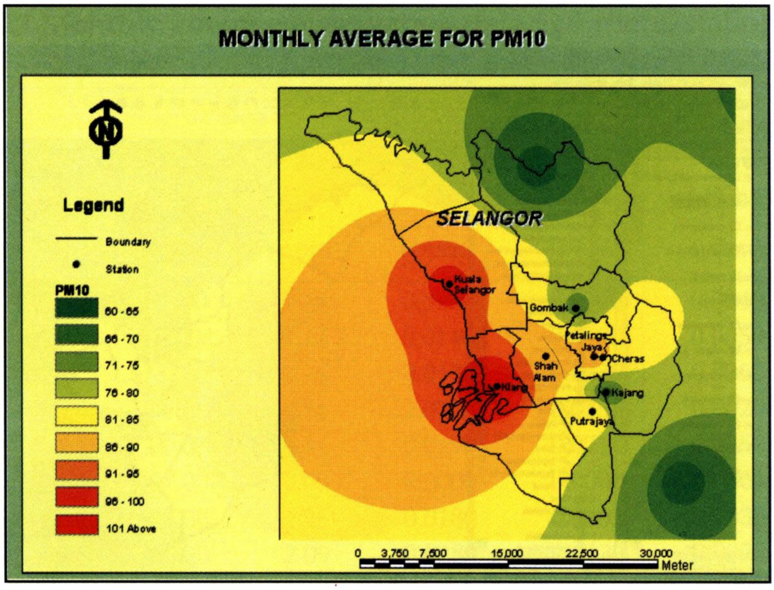

Figure 5.7 Monthly average of PM_{10} concentrations in the Klang Valley

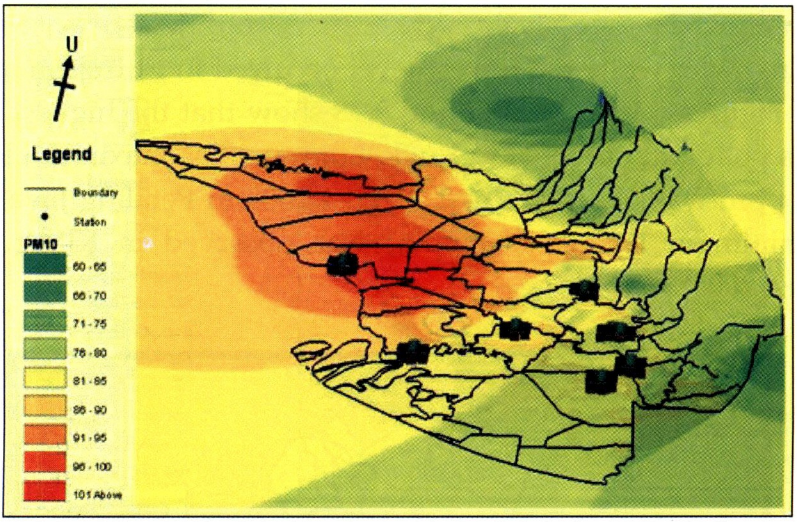

Figure 5.8 Current scenario perspective 3D view of monthly average of PM_{10} concentrations in the Klang Valley

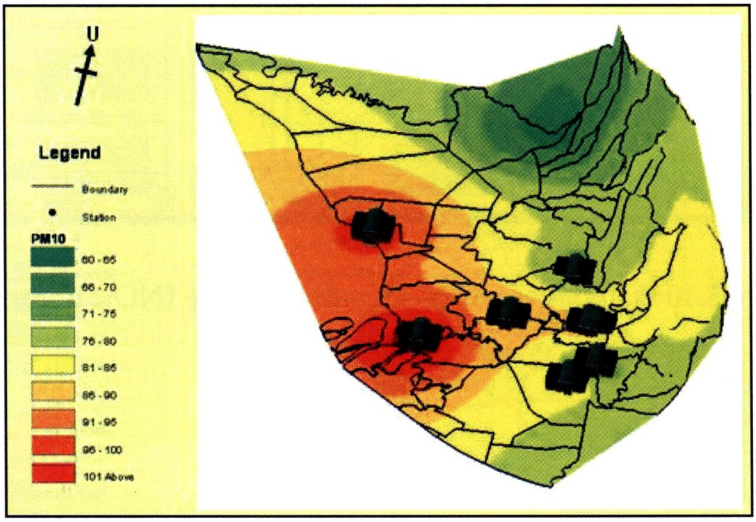

Figure 5.9 Ground level elevation 3D view of monthly average of PM_{10} concentrations in the Klang Valley

The highest average levels of NO_2 (0.033 ppm) were observed in Petaling Jaya, while the lowest level occurred in Putrajaya at 0.007 ppm. Figures 5.10, 5.11, 5.12 and 5.13 show that the highest values of this pollutant occurred in Kuala Lumpur. The maximum level of 0.050 ppm was observed on 2 August 2005 in Petaling Jaya, while the minimum level (0.003 ppm) was observed in Klang on 13 August 2005.

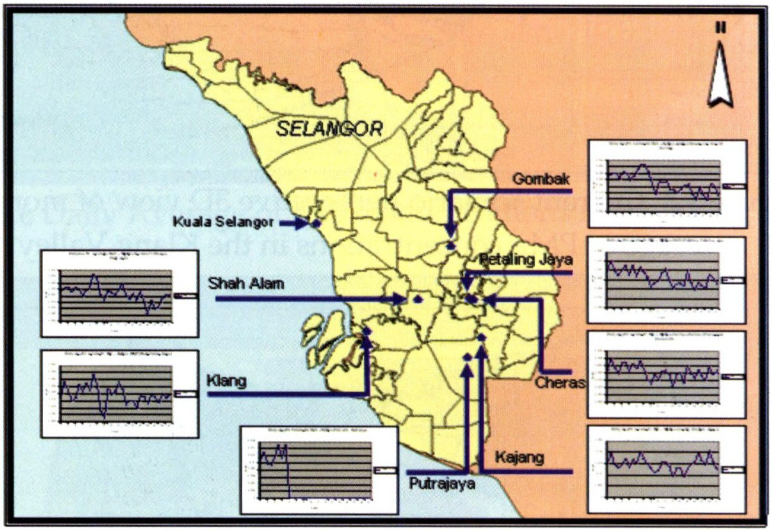

Figure 5.10 Daily average of nitrogen dioxide (NO_2) in the Klang Valley

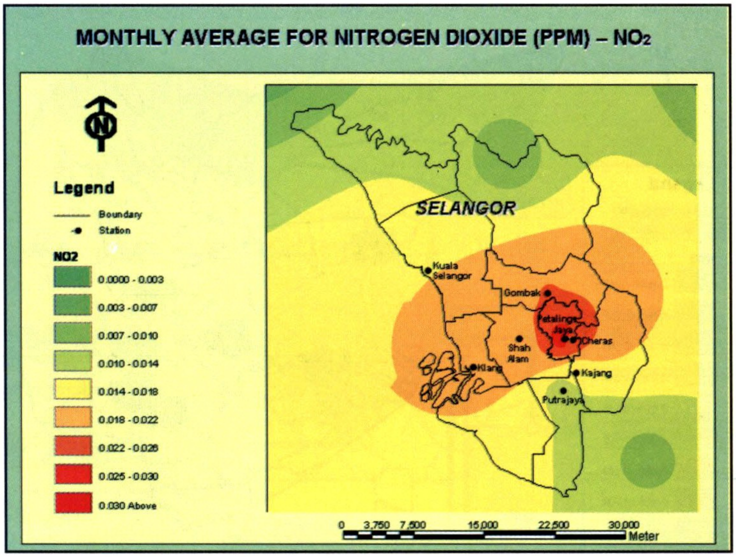

Figure 5.11 Monthly average of nitrogen dioxide (NO_2) in the Klang Valley

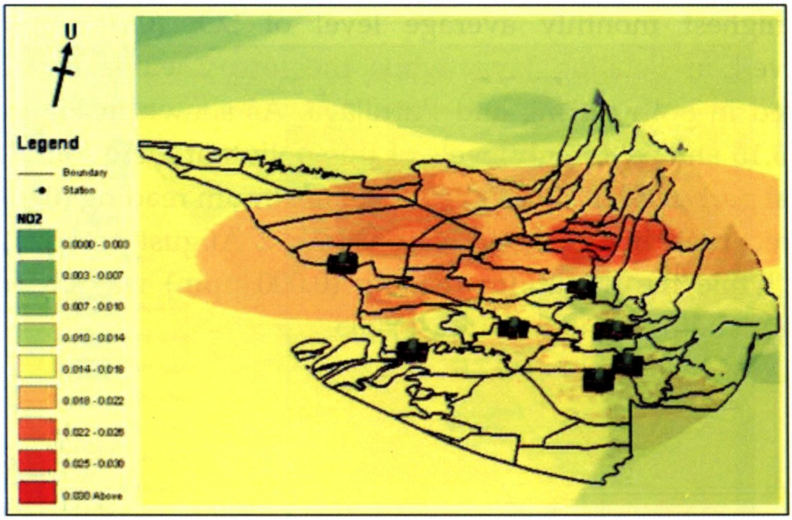

Figure 5.12 Current scenario perspective 3D view of monthly average of NO_2 in the Klang Valley

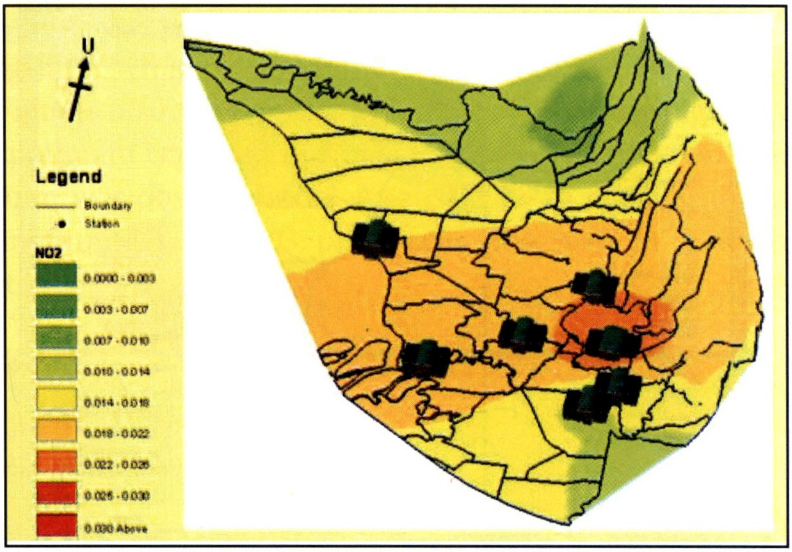

Figure 5.13 Ground level elevation 3D view of monthly average of NO_2 in the Klang Valley

The highest monthly average level of SO_2 (0.006 ppm) was observed in Petaling Jaya, while the lowest value (0.002 ppm) occured in both Kajang and Putrajaya. As shown in Figures 5.14, 5.15, 5.16 and 5.17, high levels of this pollutant were found in the central part of the Klang Valley. The maximum reading (0.010 ppm) was recorded in Petaling Jaya on both 2 August and 23 August 2005, while the minimum reading (0.000 ppm) was observed in Klang on both 14 and 31 August 2005.

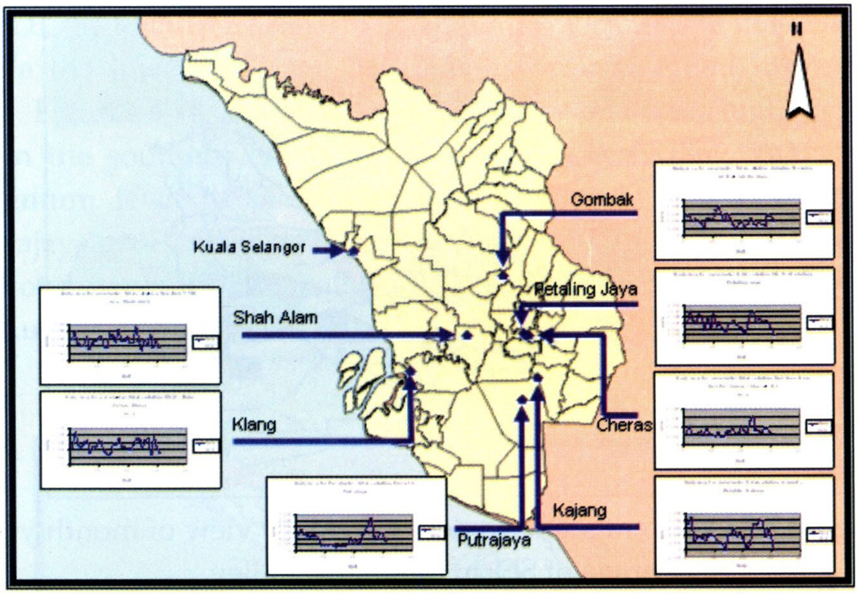

Figure 5.14 Daily average of sulphur dioxide (SO_2) in the Klang Valley

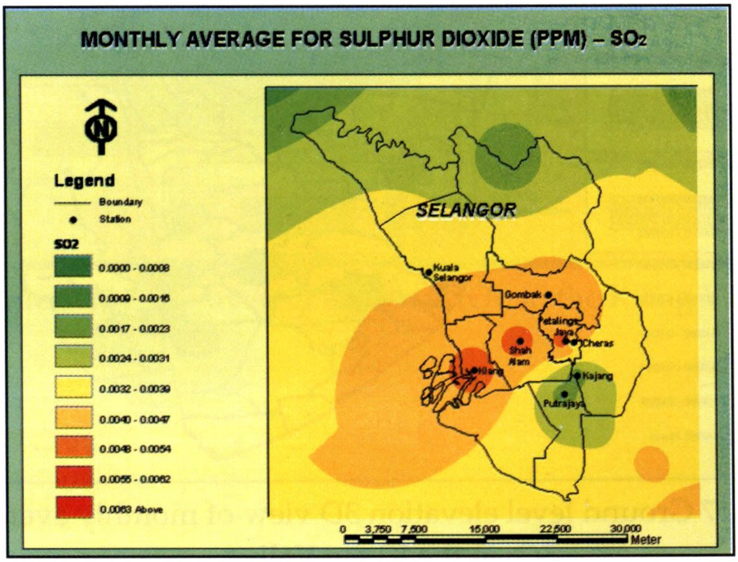

Figure 5.15 Monthly average of SO_2 in the Klang Valley

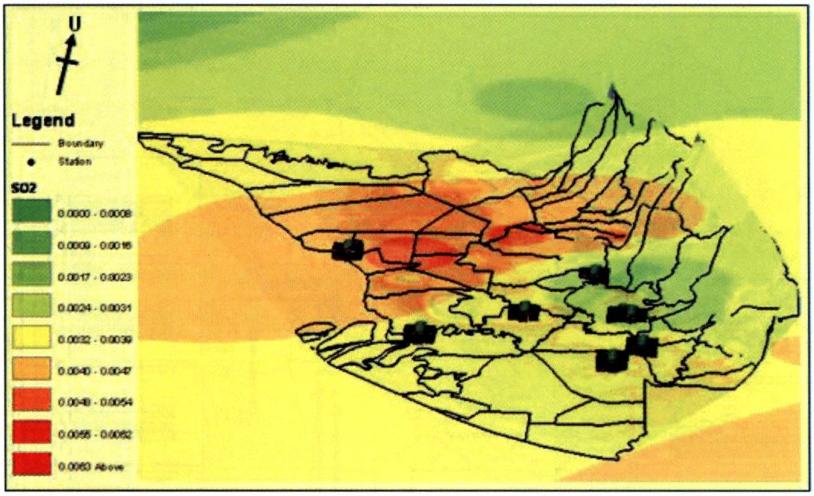

Figure 5.16 Current scenario perspective 3D view of monthly average of SO_2 in the Klang Valley

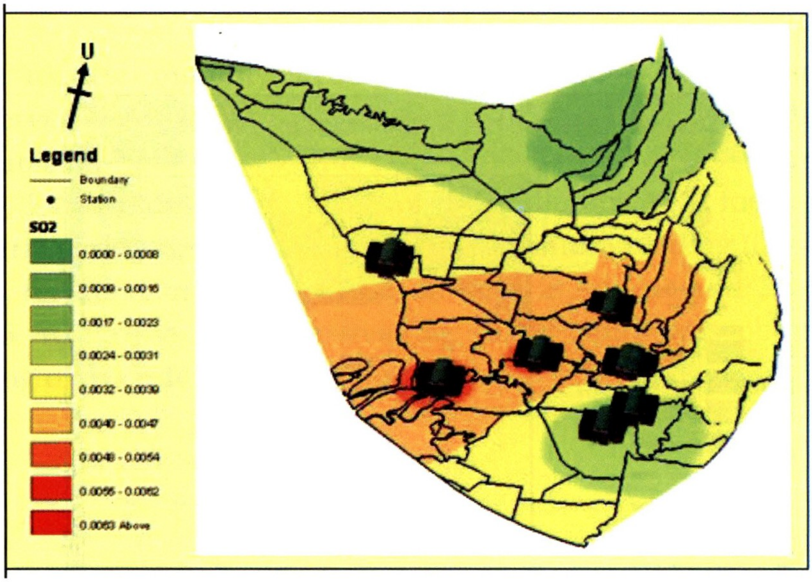

Figure 5.17 Ground level elevation 3D view of monthly average of SO_2 in the Klang Valley

For O_3, the highest average at 0.028 ppm was observed in Putrajaya, while the lowest average (0.013 ppm) was recorded in Petaling Jaya. Figures 5.18, 5.19, 5.20 and 5.21 show relatively high levels of O_3 in the southern and northern parts of the Klang Valley. The minimum level (0.050 ppm) of this pollutant was observed in Putrajaya on 17 August 2005 while the minimum value (0.007 ppm) was observed in Gombak, Petaling Jaya and Cheras, respectively on 18 August 2005.

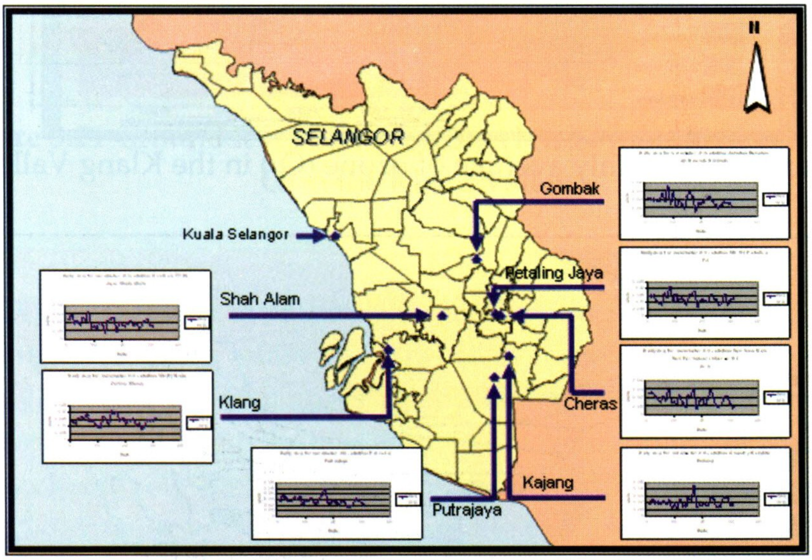

Figure 5.18 Daily average of ozone (O_3) in the Klang Valley

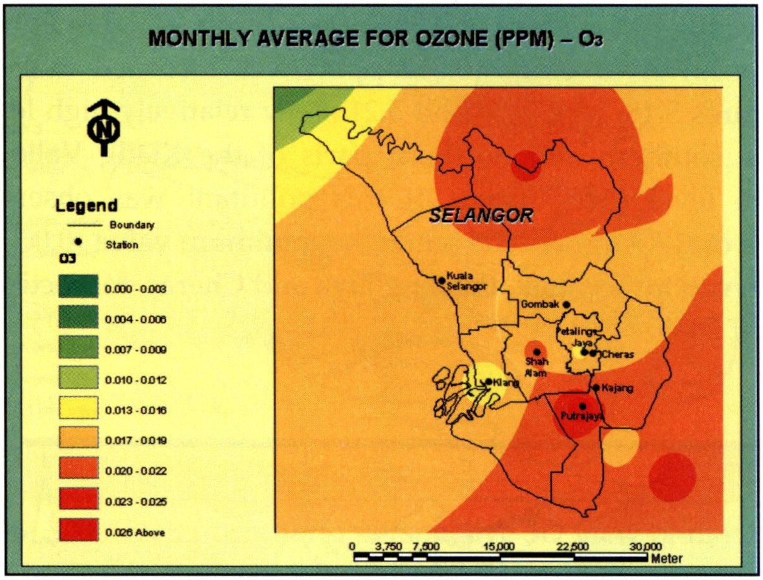

Figure 5.19 Monthly average of ozone (O_3) in the Klang Valley

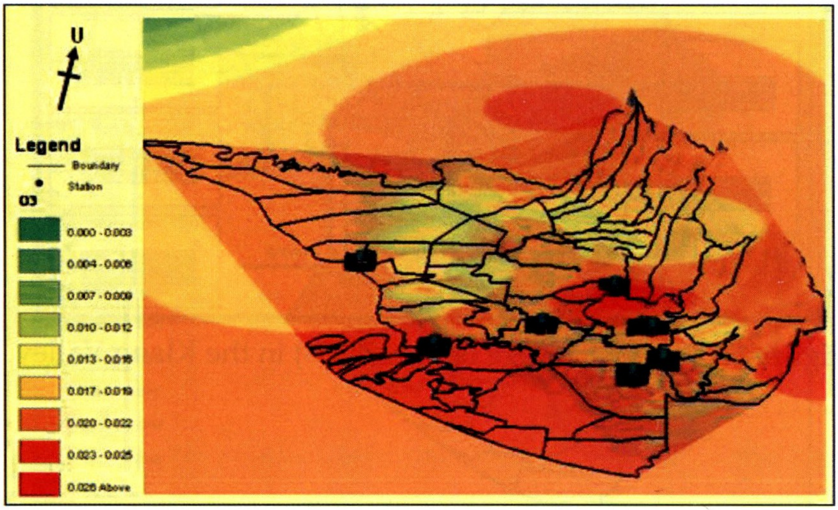

Figure 5.20 Current scenario perspective 3D view of monthly average of O_3 in the Klang Valley

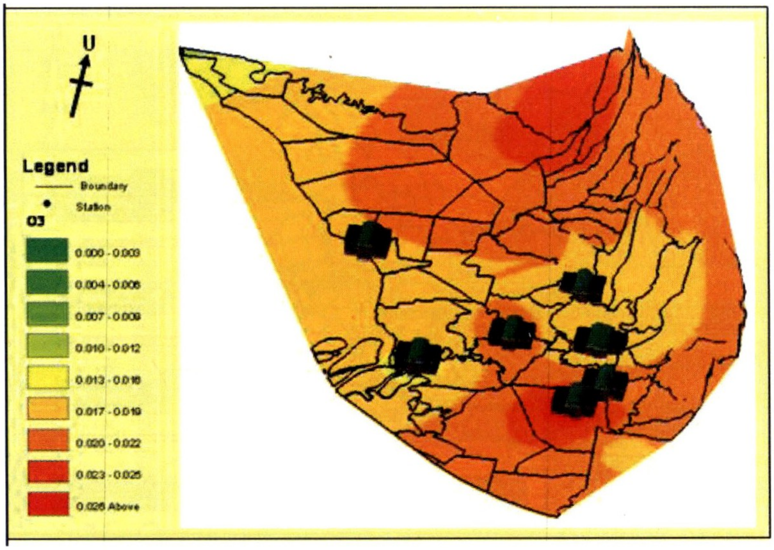

Figure 5.21 Ground level elevation 3D view of monthly average of O_3 in the Klang Valley

For CO, the highest average value (2.25 ppm) was observed in the Petaling Jaya area, while the lowest average (0.86 ppm) was in Kajang. Similar to O_3, Figures 5.22, 5.23, 5.24 and 5.25 indicate the highest levels of this pollutant were in the central parts of the Klang Valley. Relatively high readings (5-7 ppm) were recorded between 10 to 12 August in Petaling Jaya, while the lowest single reading (0.27 ppm) was in Kajang on 22 August 2005.

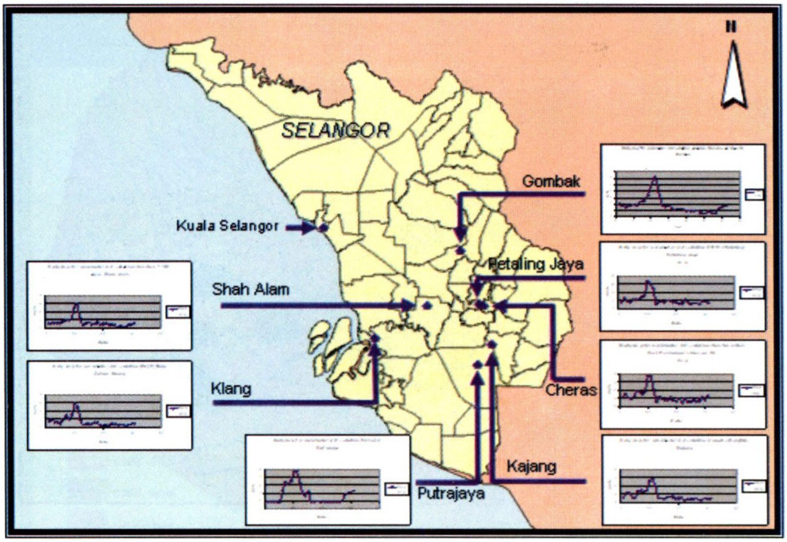

Figure 5.22 Daily average of carbon monoxide (CO) in the Klang Valley

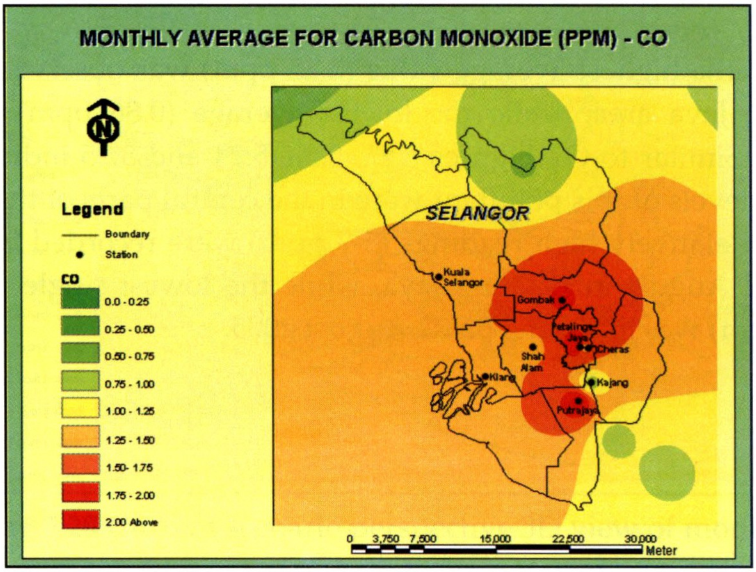

Figure 5.23 Monthly average of CO in the Klang Valley

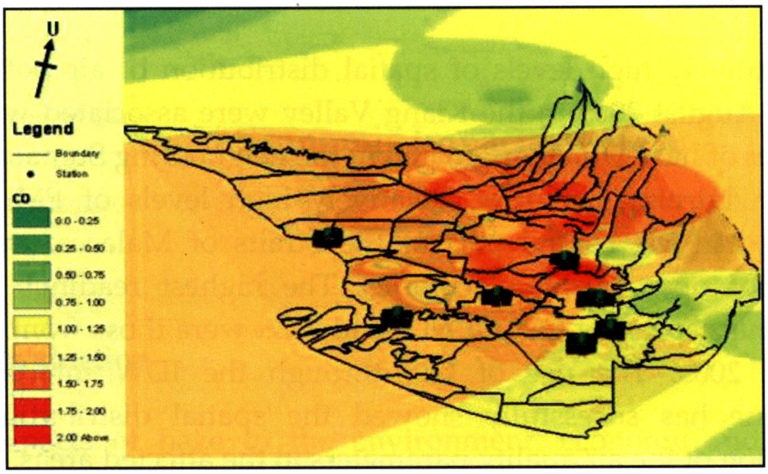

Figure 5.24 Current scenario perspective 3D view of monthly average of CO in the Klang Valley

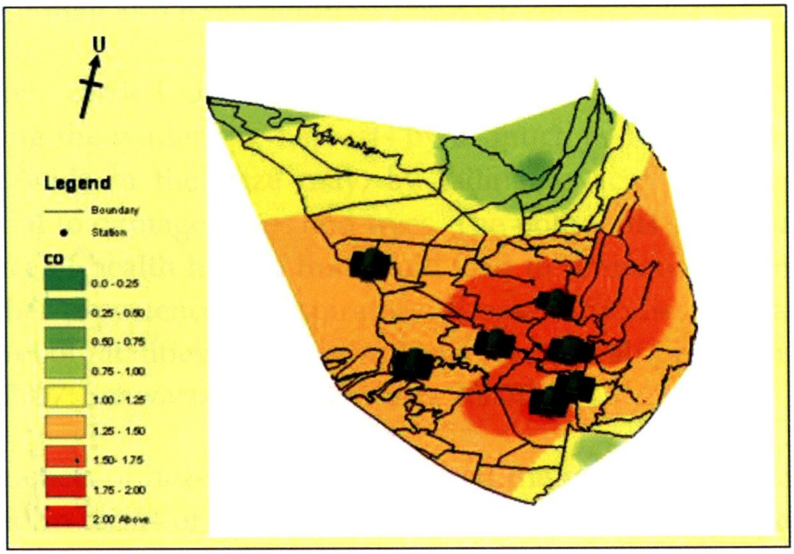

Figure 5.25 Ground level elevation 3D view of monthly average of CO in the Klang Valley

5.6. Conclusion

The relatively high levels of spatial distribution of air pollutants during August 2005 in the Klang Valley were associated with the episodes of haze which originated in the neighboring Sumatera due to open burning activities. Relatively high levels of PM_{10} were observed in the central part of the Straits of Malacca, near the source of open burning activities. The highest readings of the pollutants especially CO, O_3, NO_2 and PM_{10} were those from 9 to 12 August 2005. The use of GIS through the IDW interpolation technique has sucessfully showed the spatial distribution and dispersion of the air quality parameters in the affected areas.

CHAPTER 6

Socio-Economic Impacts of Haze

Asmah Ahmad

6.1. Introduction

The impacts of haze to the environment, economy and to the society are complex. It is known that haze reduces the levels of solar energy reaching the seas and oceans and in turn, reduces the evaporation of the moisture that controls rainfall. The reduction in sunlight may also have significant impacts on agriculture.

Research carried out in India indicates that the haze may be reducing the winter rice harvests by as much as 10 per cent (ADB, 2003) Acids in the haze may, by falling as acid rain, have the potential to damage crops and trees. The pollutants in the haze are a source of health hazard that could lead to premature deaths due to higher prevalence of respiratory diseases. Studies indicate that the level of fatalities increases with the levels of air pollution (Hajat et al., 2007; Schwartz, 1994; Schwartz 2000).

The impacts of haze have compromised the quality of life to those affected in terms of vulnerability to health, productivity, economic gains and income, as well as psychological well-being. The recurrent episodes of haze in Malaysia and their numerous, often said but least understood, impacts have created much public concern. The Department of Environment, as the official environmental gatekeeper, has taken an initiative in commissioning this report on the study of haze and its impacts. This chapter scrutinizes the impacts on human well-being, particularly health, economy and other social aspects.

6.2. Methodology

This chapter attempts to trace the impacts brought about by the 2005 haze episode. No in-depth study has been carried out to determine and measure the extent of the haze impacts, especially socio-economic impacts, as the latter is essentially to complement the study on the scientific aspects of haze. Hence, the aspects touched upon here would be exploratory in nature, based on written documents, reports, and statements. In that regard, references to secondary sources become the prime method of study.

Sources that are frequently referred to are from the local newspapers and searches via the Internet. While the former would specifically reveal the impacts or implied impacts at the local level (whose reports of outcomes of the 2005 haze episode would directly fit into the time frame considered), the latter would furnish a more general perspective of the subject matter.

6.3. Haze and Social Well-Being

By virtue of its phenomenon, haze or its incidence is normally always associated with degrading impacts. This is not surprising as its presence alone has the effect of creating uneasiness and inconveniences both physically and psychologically. In that respect, the presence of haze would undoubtedly jeopardize human social well-being or quality of life.

By definition, social well-being is the degree to which a population's needs and wants are being met (Johnston et al., 2000). It reflects the quality of life enjoyed by individuals or groups. Quality of life, on the other hand, is the state of people's social well-being as they perceived it or as it is identified by observable indicators. The latter could be attributed to the various good (and bad) elements enjoyed or endured by the population. Thus studies on quality of life normally concentrate on aspects of the human conditions pertaining to their social, economic and psychological lives (Smith, 1994, 1996; Yapa, 1996; Sutcliffe, 2001, Nurizan Yahya, 1998; Campbell, 1993).

Although social well-being as a term suffers from precise definition, it can be best understood by decomposing its dependent variables. Some consensus were achieved regarding its components (Coates et al., 1977; Miller et al., 1967; Smith, 1973), the most comprehensive is the one devised by the United Nations Research Institute for Social Development (UNRISD) (1966) which listed nine basic components of social well-being, namely, nutrition, shelter, health, education, leisure, security, social stability, physical environment and surplus income. Whilst the first three denote physical needs, the following five components denote cultural needs, while the last that is surplus income signify higher needs.

Although not all of the components of social well-being may be relevant to the current study, the aspects that would significantly be affected by the haze episode would be that of health, leisure, the physical environment, income and nutrition (from the perspective of food security). It would thus be interesting to find out how the phenomenon of haze affects human living and the quality of life.

6.4. Socio-Economic Impacts of Haze

As mentioned earlier, the impacts of haze are complex. Haze can extensively disrupt socio-economic activities, expose people to health hazards, create navigational risks due to low visibility and such like. Nevertheless, the extent or seriousness of the impacts varies with the length one is exposed to the haze, or the duration of its persistence. This is comparatively discernable between the 1997 episode and the 2005 episode. The former dragged on for about three months whilst that of the year 2005 was slightly shorter, spanning about less than half the duration experienced in 1997.

6.5. The 1997 Haze Episode

The impacts of haze from the 1997 episode are well documented. The 1997 haze episode was not only caused by external sources which exacerbated the contribution from internal sources but also coincided with the *El Nino* phenomenon which prolonged the dry season, thus providing a conducive setting for the formation of haze, which lasted for almost three months from September to November 1997.

6.5.1. Impacts on Health

One of the well-documented impacts of the 1997 haze episode pertained to health. The amounts of gaseous pollutants were significantly different compared to normal days, with the major haze contaminants being suspended particulates. Therefore the related health impacts were attributed by suspended particulates and the duration of exposure.

The 1997/1998 haze episodes had exposed about 12.4 million Indonesians in eight provinces of Riau, West Sumatra, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan, and East Kalimantan to health risk (Yudanarso, 1998). Among them 298,125 were bronchial asthma patients, 58.095 bronchitis, and 1,446,120 acute respiratory infections. It was also reported that the number of outpatients was 36,462 while that of in-patients was 15,822, the number of man-days with restricted activities were 4,758,600 and the number of restricted activities were 2,446,352. What the latter figures meant is that haze did not only affect respiratory health but had economic implications as well. A survey carried out by the Association of Indonesian Pulmonologists in West Kalimantan, where the total particulate matter (TPM) during the last week of September haze episode in 1997 was seven times higher than its normal levels was implicated with increase in respiratory-related cases.

The respiratory system is directly exposed to air pollutants. In Peninsular Malaysia, an intensive study was conducted in the Klang Valley on the lung performance of people exposed to haze pollutants such as CO, NO_2, SO_2, O_3 and PM_{10} . Although the gaseous pollutants remained below the Recommended Malaysian Guidelines (RMG) the PM_{10} was above the unhealthy level during most of September days at all six air quality monitoring stations (Hamdan, 1998).

The study also scrutinized the relationship between Air Pollution Index (API) and the main symptoms of respiratory diseases such as conjunctivitis, upper respiratory tract infection, bronchitis, and asthma in Sarawak. It was found that the incidence of these diseases was closely related to the PM_{10} concentrations. The study also revealed that obstruction of the respiratory tract in various occupational groups was related to the degree of exposure to high levels of PM_{10}.

In another instance, Odihi (2001) studied the impacts of the 1997-98 haze episodes on the health problems caused by haze on the different groups of population in Brunei Darussalam, and between its urban and rural areas. The findings pointed to the fact that adverse health effects of the haze were statistically significant and were not uniform with respect to different groups in the population. The deleterious effects of haze was found to be skewed towards the young (age 1-5 years) and the aged (≥60 years). A higher proportion of urban population was more adversely affected than in rural areas and, other things being equal, a higher proportion of outdoor workers were more adversely affected by haze than their indoor counterparts.

6.5.2. Impacts on Economy

From the economic perspective, impacts could be translated into damage costs. The latter could be accounted for air, sea and land transportation, health, tourism, and agro-based industries. Mohd Nasir (1998) attempted to calculate the long-term economic impacts of haze on health. Among the health effects measured were mortality, asthma, bronchitis, respiratory hospital admission, emergency room visit, and restricted activity days. It worked out that the estimated health cost due to TSP exposure in 1997 haze episode was RM431 million (USD168 million) when premature deaths were included, and RM108 million when premature deaths were excluded.

This figure was far higher than the Economy and Environmental Program for South East Asia (EEPSEA) short-term health damage estimate of RM20 million. The economic loss estimated by EEPSEA was USD1.38 billion, in which USD310 million (RM794 million) were incurred in Malaysia, USD63 in Singapore, and USD1012 million in Indonesia. The loss in Malaysia included the economic damage and the abatement costs, such as fire fighting, monitoring and enforcement activities.

The economic implications of haze were also immediate as well as expected to be long term. Tourism in the entire Southeast Asian region dropped off considerably in combination with the stock market decline. Indeed, it is possible to see a link between the loss of economic confidence and the smoke haze issue. Many previous hotels and holiday bookings were cancelled especially in Malaysia and Indonesia.

6.5.3. Impacts on Agriculture and Food Security

Rice production in Indonesia is heavily influenced by the monsoon rain patterns, which have an important bearing on agricultural performance during the main (wet) and secondary (dry) seasons. The wet season normally extends from October to March and produces 60 percent of the country's annual rice crop and half of its maize, soybean and groundnuts. The dry season covers April to September, during which the remaining annual crop is produced.

The rainfall anomalies during the wet season of 1997-98 caused a decrease in area under rice cultivation by 380,000 ha (3.4% below the previous wet season) (ADB, 2003). Farmers planted maize as a compensatory crop in areas where paddy could not be planted. The switching over to maize was to the extent of 266,000 ha more than the area normally cropped with maize (an 8% increase from the previous wet season). The reduced rice production, coinciding with the economic crisis that began in 1997, led to a 300 percent increase in the price of rice. The Indonesian Government imported over five million tons of rice to maintain price levels and to ensure the availability of food to the economically weaker sections of the population.

In Irian Jaya (Indonesia's easternmost province), severe drought had caused staple food crops to fail in the highlands, resulting in an estimated minimum of 500 deaths from mass starvation (Dudley, 1997). The death toll was reported to rise as smoke haze from extensive fires, also burning in this mountainous province, hampered visibility and access by airplanes directed at providing emergency food relief. A regional news report alleged some 90,000 people were reported to be facing imminent starvation from the continuing famine in mid-November 1997, when the first wet season rains had not fallen, and the fires and associated smoke haze continued.

6.5.4. Impacts on the Forestry Sector

The widespread occurrence of forest fires during the 1997-98 El Niño with associated smoke and transboundary haze also contributed to a significant socio-economic impact. A study commissioned by Asian Development Bank (ADB) and *Badan Perencanaan Pembangunan Nasional*, Indonesia (BAPPENAS) (ADB and BAPPENAS, 1999) estimated the economic cost of the 1997-98 fires and drought to be in excess of USD9 billion. Besides Indonesia, a number of Southeast Asian countries, in particular Brunei Darussalam, Malaysia and Singapore, were badly affected. The Philippines and Thailand also suffered, although to a lesser degree.

The scope of the pollution resulting from the fires, especially those from peat soils and cleared forests, showed that the impact was an environmental problem of global dimensions. In 1997-98, the forest and land fires in Indonesia contributed 22 percent of the world's carbon dioxide production (Page et al., 2002). Over 700 million tons of carbon dioxide was released into the atmosphere, elevating Indonesia to being one of the largest carbon polluters in the world.

6.5.5. Impacts on Safety

By virtue of its effect on visibility, haze could become a potential safety hazard. Nevertheless, during the 1997 haze episode, serious transport accidents appeared to have been more than coincidental during the smog period (Frodsham et al., 2000). A report had it that a Garuda Airbus collided into a mountainside on the approach to Medan in Sumatra, killing all 256 passengers on board. Shortly afterwards airports were closed at Medan and at other terminals in the country. Meanwhile, in the hazy Straits of Malacca, a small Indian cargo vessel hit a large supertanker, killing 20 of the former ship's crew. It thus seemed that the haze exacerbated many traffic accidents (Frodsham et al., 2000).

6.6. The 2005 Haze Episode

In contrast to the 1997 haze episode, the 2005 haze episode (although severe) was of shorter duration and was mainly due to hundreds of hotspots detected in Riau and Sumatera Utara. The sudden thick haze had reduced ground visibility to as low as one kilometer in parts of Selangor, particularly in Sepang and Petaling Jaya, while it was worse in Seremban when ground visibility was down to 500 m. In fact, according to Plus Expressway visibility at some stretches of the Elite Expressway was only 150 m (*New Straits Times,* 2005a). With such low visibility, the impacts of the 2005 haze episode were mainly associated with health and safety hazards. Nonetheless, other socio-economic impacts were also implicated.

6.6.1. Haze and Health Hazards

With the onset of sudden and thick haze in the early month of August 2005, the media had been issuing early warning for the public to limit outdoor activities as haze could cause irritation and breathing problems. As a consequence, the worsening haze had made people shied away from popular haunts in the city of Kuala Lumpur, which appeared to be deserted. Hospitals too were put on alert. All government hospitals and public health clinics were directed to prepare for an increase in incidences of respiratory problems, coughs, sore throats and eye irritations (*New Straits Times,* 2005b).

As the haze endured in Malaysia, increased reports of haze-related illnesses began to appear in the media. Within one week from the onset of the haze, more people were complaining of respiratory tract infections, conjunctivitis or "red eye" and sore throats in the Klang Valley with the worsening haze. As a result, people working outdoors were advised to use protective masks, respirators or other protective equipment. Those in affected areas were also advised to stay indoors and increase their fluid intake to prevent their throats from drying out.

The number of people seeking medical treatment, especially for asthma, respiratory infection and conjunctivitis in the Klang Valley, Seremban and Nilai had increased significantly. The increase of asthma cases in Seremban and Nilai was up to 150 percent while the number of patients in the Klang Valley had risen as high as 10.7 percent (*New Straits Times,* 2005d). This was further supported by another report made by the University Malaya Medical Centre respiratory division head, which mentioned that more people were facing upper respiratory problems that might lead to fainting spells, and that the Centre recorded a 5 percent increase in the number of patients being treated for severe asthma attack (*New Straits Times*, 2005f).

As the haze worsened, unhealthy air quality was recorded in eight locations i.e. Ipoh, Seri Manjung and Tg. Malim in Perak; Petaling Jaya, and Kuala Selangor in Selangor; Kuala Lumpur; and Nilai and Seremban in Negeri Sembilan, so much so that directive was issued for schools to be closed in areas where the API reached over 300. When the API rose above 400, some parts in Selangor were declared as haze emergency zones. Residents were also advised that should the API reached dangerous level of over 500, they were to close all windows and stay at home, switching on the air conditioner (where applicable), to refrain from conducting outdoor exercises, and/or wore mask during outings. Two areas in Selangor had breached the dangerous limit i.e. Kuala Selangor, (531) and Port Klang (529). Most schools were closed.

Fear had it that childhood cancer might develop when exposure to air pollution occurred in the early life. Chemicals emitted by cars, particularly diesel engines, could have caused cancer in children and the rate of childhood cancer was reported to have been rising over the past three decades (*New Straits Times,* 2005f). Where fatality was concerned, only one death i.e. that of an 83 year-old man, was reported at that time whose family believed that his death was caused by haze. However, by August 15, at least 7 haze-related deaths were recorded in Selangor (*New Straits Times,* 2005g). Although only very few people were reported to have died from respiratory problems as a result of the fires, the true long term health effects of the millions of people living in the worst affected areas will not be ascertained for many years to come.

6.6.2. Haze and Safety Hazards

The smoky characteristics of haze have a profound impact in reducing visibility. In that respect it is potentially hazardous to physical safety in as far as transportation via overland route, aviation and sea-lanes are concerned. With progressing thick haze by August 10, visibility alert for ships plying the busy Straits of Malacca was issued to avoid collision when visibility was reduced to about 1 km in the middle and south of the straits. Nevertheless, no untoward incident was reported.

6.6.3. Haze and the Economic Costs

The economic losses from the raging forest fires in Indonesia alone were estimated to be around USD10 billion (RM376 billion) (Qadri, 2001). Not only timber yield was wasted, agricultural productivity too seemed to be impacted. The haze in the Sumatera was reported to have slashed Indonesian palm oil production by 15 percent in August. Production was down to 900,000 tonnes, which undoubtedly cause a reduction in export, previously expected to reach around 800,000 tonnes (*New Straits Times*, August 25, 2005). Reduced production was brought about by the disruption of harvesting activities due to haze in Riau and Kalimantan.

Disruption of economic activities occurred across the board. Not only was agriculture industry affected, others comprising large and small ventures such as businesses and construction industry were also impacted. The major groups whose daily income had been affected were the food businesses, construction workers, farmers and the fishing communities. Reduced outings and outdoor activities undoubtedly had caused vendors to lose their clientele or even to close operation during the haze episode. The construction industry too had been affected by the persistent haze.

The closure of construction sites and food businesses had not only cost the workers and individuals their revenue and income forgone, but so were the organizations and enterprises employing them. Decreased workdays would have resulted in losses incurred to the organization in terms productivity as well as time lost and delayed completion, hence reduction in profit margin.

Nevertheless, the haze pollution could boost other businesses such as the sales of mask and treatment of haze-triggered patients.

Another badly hit sector was the tourism industry. The haze caused the cancellation of many tours and hotel accommodations.

The preceding discussions have shown how the impacts of haze had inconvenienced daily life and affected the well-being and hence, the quality of life of the affected population. The health, safety, food security, income, leisure etc. were threatened and in some instances forgone. Lessons should be learnt from the ordeal of facing and dealing with the haze hazards, but the solutions for it would only be effective if the causative factors behind it were understood. It is beyond this paper to touch upon the causative factors of haze (some of which have been dealt elsewhere in other chapters), however, the potential solution would be touched upon briefly in the following conclusion.

6.7. Conclusion

The current chapter is at best a compilation of writings on previous haze episodes and their respective impacts in the region as reported by individuals based on observations, interviews and research findings. As such, they are but snippets of information here and there, which do not impart the wholesome impact as experienced by a community or a region. For these impacts to be better understood, it is envisaged that a study be conducted and focused on a community or a region that is most vulnerable to the occurrences of haze. In so doing, the totality of the haze impacts on the community and region could be discerned and be better comprehended. It is this understanding that could help educate the general public regarding the woes of haze and subsequently its origin, dimension and awareness of one's role and contribution towards its reduction.

The recurrent haze episode of late and its transboundary nature as well as the impacts that such crisis had on the environment and mankind calls upon suggestions for solutions. Time and time again meetings, talks, appeals, cooperation were organized, broadcasted and mooted from among the affected parties and governments when faced with such a crisis. Potential solutions for the problems suffered are multifaceted.

What had been suggested socio-economically are cooperative efforts amongst ASEAN governments to reduce poverty in communities that burn forests; improve their socioeconomic opportunities; lessen their dependence on land; and share information related to haze to prevent or mitigate its adverse effects. There is also a need for greater and sustained programmes of educating the public on environmental hazards to mitigate their adverse impacts on society. An ecological crisis is of considerable interest to those examining the issues of sustainability (environmental as well as economic, as they are linked inextricably).

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