



UNIVERSITI PUTRA MALAYSIA

CHARACTERIZATION OF HAZE PARTICULATE MATTER

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FSAS 2003 17

CHARACTERIZATION OF HAZE PARTICULATE MATTER

By

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Master**

April 2003



DEDICATION

This thesis is especially dedicated to my family and friends who have been giving me lots of support, advice and encouragement in my studies.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment
of the requirements for the degree of Master of Science

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April 2003

Chairman: Dr. Ahmad Makmom Abdullah

Faculty: Science and Environmental Studies

Haze has become a public concern especially after the 1997 haze episode which resulted from large-scale forest fires that caused transboundary spreading of air pollution. Particulate matters are primarily responsible for creating haze in the atmosphere as well as adverse effects on human health. Thus, both of the physical and chemical characteristics of particulate matters are important when attempting to elucidate particle toxicity. Particulate matters, which aerodynamic diameter equal or less than 10 μm (PM_{10}) were measured in the periods from 1997 to 2000 at UPM station. High volume sampler (HVS) was used to collect most of the ambient particle samples and a small portion was collected using particle counter. Sampling of particulate matter was carried out from various emission sources such as peat swamp fire at Sepang, biomass burning at paddy field and several types of vehicle exhaust. Besides that, simulated peat soil and rice straw burning were also conducted in the fumigation chamber to collect particulate matter. Chemical analysis was performed by atomic absorption spectrophotometer (AAS) to identify ten kind of common trace metals, namely potassium (K), zinc (Zn), magnesium (Mg), sodium (Na), calcium (Ca), iron (Fe), manganese (Mn), lead (Pb), chromium (Cr) and copper (Cu). The



monitoring of PM₁₀ reveals that haze episode was not only due from transboundary air pollution, but also originated from local sources such as peat swamp fire. Meteorological parameters such as temperature, wind speed and rainfall show extremely low correlation with PM₁₀ concentrations and also trace metals content in PM₁₀. Particle number concentrations with the aerodynamic diameter of 0.3 μm and 0.5 μm were noticeably higher during the high traffic intensity and haze periods. The fluctuation of particle number concentrations with the aerodynamic diameter of 5.0 μm and 10.0 μm indicate that the variations of coarse particle are more influenced by meteorological factors. Among the measured trace metals in this study, Na, Cr and Fe show significant difference between normal atmospheric condition and hazy condition. The chemical profiles of TSP from peat swamp fire and simulated peat soil burning were nearly similar, which indicate K, Fe and Mn dominate the smoke particle from peat swamp fire. K is the main element that is present in TSP from paddy residue and rice straw burning. On the other hand, Ca and Fe are the main species in PM₁₀ released by 2-stroke motorcycles. Compared with petrol powered engine, diesel powered engine emitted less quantity of trace metals except Zn, Ca and Pb. Scanning Electron Microscope (SEM) demonstrated that majority of the haze particles were smaller than 2.5 μm and agglomerate in structure, comprising of a number of individual spheres and liquid droplets. The particle samples collected from peat swamp fire tend to form the compound of clusters up to 10 μm, which are larger than the particles produced from rice straw burning. 2-stroke motorcycle exhaust emission generates particles that appeared as the formation of clusters without clear boundary between the particles. For the diesel exhaust particles, the large agglomerated “spherules” was formed and the entire individual particle was in the range of < 2.5 μm in diameter.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENCIRIAN BAHAN PARTIKULAT JEREBU

Oleh

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Jerebu telah menjadi isu perhatian awam terutamanya selepas episod jerebu 1997 akibat pembakaran hutan dan telah menyebabkan pencemaran udara melintasi sempadan secara meluas. Partikulat adalah bertanggungjawab pembentukan jerebu dalam atmosfera dan seterusnya mendatangkan kesan buruk kepada kesihatan manusia. Oleh yang demikian, kedua-dua ciri fizikal dan kimia partikulat adalah penting untuk pentafsiran keracunan partikulat. Pengukuran partikulat yang bergarispusat aerodinamik sama dengan atau kurang daripada $10 \mu\text{m}$ (PM_{10}) telah dijalankan dari tahun 1997 hingga 2000 di stesen UPM. Penyampel berisipadu tinggi (HVS) telah digunakan untuk mengumpul partikulat dalam udara manakala sebahagian kecil partikulat dikumpul dengan menggunakan alat pengira partikulat. Pengumpulan partikulat telah dijalankan dari pelbagai punca seperti pembakaran hutan tanah gambut di Sepang, pembakaran biomes sawah padi dan gas ekzos dari pelbagai jenis kenderaan. Di samping itu, pembakaran simulasi tanah gambut dan batang padi juga dijalankan di dalam kotak uji untuk mengumpul bahan partikulat. Analisis kimia dijalankan dengan menggunakan spektrofotometer penyerapan atom (AAS) untuk menentukan sepuluh jenis logam biasa, iaitu potassium (K), zink (Zn),

magnesium (Mg), sodium (Na), kalsium (Ca), ferum (Fe), manganese (Mn), plumbum (Pb), chromium (Cr) dan kuprum (Cu). Pemonitoran PM₁₀ mendapati episod jerebu bukan sahaja berpunca dari pencemaran udara melintasi sempadan, tetapi juga dihasilkan dari punca tempatan seperti pembakaran tanah gambut. Parameter meteorologi seperti suhu, laju angin dan hujan menunjukkan korelasi yang terlalu rendah dengan kepekatan PM₁₀ dan juga kandungan logam dalam PM₁₀. Kepekatan bilangan partikulat dengan garispusat aerodinamik 0.3 µm dan 0.5 µm didapati tinggi pada waktu kesesakan trafik dan kejadian jerebu. Ketidaksetaraan kepekatan bilangan partikulat dengan garispusat aerodinamik 5.0 µm dan 10.0 µm mencerminkan variasi partikulat kasar adalah lebih dipengaruhi oleh faktor meteorologi. Di antara logam yang diukur dalam pengajian ini, Na, Cr dan Fe menunjukkan perbezaan yang bermakna antara keadaan atmosfera normal dan jerebu. Profail kimia jumlah partikulat terampai (TSP) dari pembakaran tanah gambut dan simulasinya adalah hampir sama, yang mana K, Fe dan Mn merangkum partikulat asap dari pembakaran tanah gambut. K merupakan unsur yang utama dalam TSP dari pembakaran sisa padi dan batang padi. Di samping itu, Ca dan Fe adalah species utama dalam PM₁₀ yang dibebaskan oleh motorsikal 2-lejang. Perbandingan dengan enjin petrol, enjin diesel membebaskan kurang kesemua logam kecuali Zn, Ca dan Pb. Mikroskop pengimbasan elektron (SEM) menggambarkan kebanyakan partikulat jerebu adalah lebih halus dari 2.5 µm dan bergabung dengan beberapa sfera individu lain dan titisan cecair. Partikulat dikumpul dari pembakaran tanah gambut berkecenderungan membentuk sebatian “clusters” sehingga 10 µm yang lebih besar daripada partikulat hasil dari pembakaran batang padi. Pembebasan ekzos motorsikal 2-lejang menghasilkan partikulat dalam bentuk “cluster” yang tidak mempunyai sempadan jelas antara partikulat. Untuk partikulat ekzos diesel,

gabungan besar “spherules” dibentuk dan kesemua partikulat individu adalah dalam lingkungan garispusat $< 2.5 \mu\text{m}$.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere appreciation to my supervisor, Dr. Ahmad Makmom Abdullah for his invaluable help, encouragement and advice throughout my research work. His helpful comment always guides me to solve the problems during my experiment to make this project successful.

My appreciation of special thanks is also extended to my co-supervisors Prof. Dr. Wan Md. Zin Wan Yunus and Prof. Madya Dr. Dzulkefly Kuang. Their untiring guidance and counsel has been a constant source of inspiration and motivation during my master study.

I am deeply indebted to En. Shamsuddin Johan and En. Marzuki Ismail for their invaluable advice and assistance that has contributed substantially during the process of my Master studies.

I have benefited greatly from the laboratory assistants in both Department of Environmental Sciences and Department of Chemistry, especially En. Zaman Jais, En. Sujak Samad, En. Mat Kamal Margona and En. Zainudin Samadi for assisting me in my chemical analysis.

Without the enduring patience, warm encouragement and active support of my parents, I would never complete my study smoothly. No brief mention can adequately convey my appreciation to these people, but I hope the outcome warrants their support.



I certify that an Examination Committee met on 23rd April 2003 to conduct the final examination of Lau Tai Meng on his Master of Science thesis entitled “Characterization of Haze Particulate Matter” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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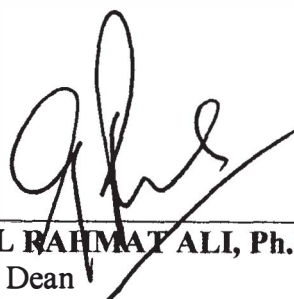
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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



LAU TAI MENG

Date: 17 July 2003

TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	viii
APPROVAL SHEETS	ix
DECLARATION FORM	xi
LIST OF TABLES	xv
LIST OF FIGURES	xvii
LIST OF ABBREVIATIONS	xx
 CHAPTER	
I	INTRODUCTION 1
	Atmospheric Aerosols 1
	Biomass Burning 3
	Fine Airborne Particle on Health Effects 4
	Impact of Haze Episode on Economy and Accidental Cases 7
	Objectives of the Study 8
	Significance of the Study 8
	Scope of the Study 9
II	LITERATURE REVIEW 11
	Air Quality Study in Kang Valley 11
	Physico-chemical of Airborne Particle 12
	Biomass Burning and Peat Swamp Fire 16
	Vehicle Exhaust Emission 17
	Legislative Standard 19
III	MATERIALS AND METHODS 21
	Sample Collection 21
	Ambient air 21
	Particle Sizing 23
	Peat Soil Burning Measurement 24
	Biomass Burning Measurement 27
	Vehicle Exhaust Emission 29
	Meteorological Data 30
	Elemental Analysis 31
	Statistical Analysis 32
	Morphological Analysis 32



IV	RESULTS AND DISCUSSION	33
	Daily PM ₁₀ Concentrations	33
	Correlation between PM ₁₀ Concentrations and Meteorological Conditions	35
	Temperature	35
	Wind Speed	37
	Rainfall	41
	Particle Distribution	46
	Correlation between Different Particle Size Distributions, Temperature and Relative Humidity	51
	Chemical Properties	55
	Airborne Particles	55
	Inter-species Correlation	58
	Correlation between Elemental Content and Meteorological Condition	58
	Hazy Day	58
	Wind Speed	64
	Rainfall	67
	Peat Swamp Fire Emission	68
	Simulated Peat Soil Burning	69
	Biomass Burning Emission	74
	Simulated Rice Straw Burning	79
	Vehicle Exhaust Emission	83
	Petrol Exhaust Particle and Diesel Exhaust Particle	83
	Correlation between Elemental Content and Traffic Intensity	90
	Morphological Analysis	94
V	CONCLUSION	105
	REFERENCES / BIBLIOGRAPHY	110
	APPENDICES	118
	Appendix 1: Average source contributions to selected SPM samples collected in the Klang Valley region between 1991-1993	118
	Appendix 2: Emission of pollutants to the atmosphere by source in Malaysia (1995-1999)	119
	Appendix 3: Emission of pollutants to the atmosphere by type from mobile source in Malaysia (1995-1999)	119
	Appendix 4: Number of mobile sources in Malaysia, 2000	120
	Appendix 5: National Ambient Air Quality Standards (NAAQS) set by the United States Federal Government	121
	Appendix 6: Recommended Malaysia Air Quality Guidelines	122
	Appendix 7: Particulate matter and gases sampling system for vehicular exhaust emission	123
	Appendix 8: Meteorological data and PM ₁₀ concentration during sampling periods	124



Appendix 9: Monthly average concentration of PM ₁₀ in the air (µg m ⁻³) within Klang Valley (1995-2000)	127
Appendix 10: Series of PM ₁₀ concentration with meteorological variables for 125 samples	128
Appendix 11: Statistical Analysis between PM ₁₀ and Meteorological Parameters	129
Appendix 12: Particle number measured by particle counter in the period August-September 1999	131
Appendix 13: The elemental compositions of airborne PM ₁₀ mass concentrations collected at UPM station (µg m ⁻³)	136
Appendix 14: Regression Analysis between PM ₁₀ and Trace Metals Concentration	137
Appendix 15: Comparison of PM ₁₀ Trace Metals Concentration between Hazy Day and Normal Day	138
Appendix 16: Regression Analysis of PM ₁₀ Trace Metals Concentration with Wind Speed	142
Appendix 17: Regression Analysis of PM ₁₀ Trace Metals Concentration with Rainfall	147
Appendix 18: Comparison of Total Trace Metals Concentration in PM ₁₀ between Raining and Non-raining Day	152
Appendix 19: Comparison of Total Trace Metals Concentration (in %) between Petrol Exhaust Particle and Diesel Exhaust Particle	152
Appendix 20: Comparison of Total Trace Metals Concentration in PM ₁₀ between Mid-Semester Break and Lecture Season	153
BIODATA OF AUTHOR	157



LIST OF TABLES

Table		Page
1	Assumptions used in Nominal Dose Calculations	5
2	Comparison of the measured species concentrations (in $\mu\text{g m}^{-3}$) of metals in Australia, Singapore and Hong Kong that published in the literature	13
3	The concentration of atmospheric trace metals in Petaling Jaya, 2000	14
4	The derived composition profiles of traffic exhausts on Brisbane roads (in $\% \text{g g}^{-1}$)	18
5	Summary of samples collected in Klang Valley region during haze episode in September 1997	38
6	Correlation between the number of different particle size distributions, temperature and relative humidity	51
7	The elemental compositions of airborne PM_{10} mass concentrations collected at UPM station ($\mu\text{g m}^{-3}$)	56
8	Correlation matrix of trace elements in PM_{10}	58
9	Mean elemental concentrations in the categories of $\text{PM}_{10}<70$ and $\text{PM}_{10}>70$; with mean concentration ratios and <i>p</i> -value between both categories	61
10	Comparison of the measured species concentrations (in % of aerosol mass) in haze sample collected from UPM and Brunei Darussalam	63
11	Summary of regression statistics between measured elements with the mean wind speeds (summarized from Appendix 16)	64
12	Summary of regression statistics between measured elements with the rainfalls (summarized from Appendix 17)	67
13	Trace metals concentration in TSP ($\mu\text{g m}^{-3}$) with percentages of mass from peat swamp fire and peat soil burning emission	69
14	Trace metals concentration in TSP ($\mu\text{g m}^{-3}$) from paddy field burning. The values given in parentheses are the percentages of respective element in the TSP mass	75
15	PM_{10} concentrations collected from PEP and DEP	84



16	Correlation matrix of trace elements in PEP and DEP collected from various types of vehicle	89
17	PM ₁₀ concentration with corresponding meteorological parameters collected in UPM campus during mid-semester break and lecture season	91
18	Correlation matrix of trace elements in PM ₁₀ collected in UPM campus during mid-semester break and lecture season	93



LIST OF FIGURES

Figure		Page
1	Malaysian annual average PM ₁₀ concentration, 1996-2000	13
2	Schematic diagram of High Volume Sampler, Anderson Instruments, USA (model: B/M2000HX)	23
3	The laser scattering particle counter (model: HIAC/ROYCO Portable Plus)	24
4	Map of Selangor State – location of three sampling sites	25
5	Smoke from Sepang peat swamp fire polluted the surrounding atmosphere and the smoke particulate was collected by HVS	25
6	The HVS was set up beside a highway at Sepang to collect the background data in normal day	26
7	Sampling system to collect smoke particles from simulated burning of peat soil and rice straw	27
8	Particulate matter generated from paddy field fire was collected by HVS	29
9	Daily concentrations of particulate matter (PM ₁₀) collected at UPM station from 1997 to 2000	34
10	Daily average PM ₁₀ concentration and temperature for the entire sampling period	36
11	Scatter diagram showing PM ₁₀ concentrations and temperature	37
12	Daily average PM ₁₀ concentration and wind speed for the entire sampling period	40
13	Scatter diagram showing PM ₁₀ concentrations and wind speed	41
14	Daily average PM ₁₀ concentration and rainfall for the entire sampling period	43
15	Scatter diagram showing PM ₁₀ concentrations and rainfall	44
16	Time series of particles count in different size per m ³ (a) 0.3 µm; (b) 0.5 µm; (c) 5.0 µm; (d) 10.0 µm; and (e) meteorological variables for the mean values of ten samples measured at UPM station	49-50

17	Time series variation of aerosol number concentrations (particles m^{-3}) in UPM campus during non-haze and hazy periods on 20 August (Low PM_{10}) and 14 September (High PM_{10}), 1999. The first-four-panel (a)-(d) is for the size range of $0.3 \mu m$ - $10.0 \mu m$ and another two-panel (e)-(f) are meteorological variables during sampling periods	53
18	Samples with their PM_{10} concentrations	55
19	Distribution of the element concentrations in the samples	57
20	Scatter diagram between PM_{10} concentrations and the fraction of measured elements in the samples	59
21	Average mass concentrations of 10 measured inorganic elements in PM_{10} concentrations lower and higher than $70 \mu g m^{-3}$	60
22	The relation between measured element concentrations and wind speed	65- 66
23	TSP concentrations from the different mass of peat soil burning in closed chamber	70
24	Concentrations of measured elements from different sampling sources	72
25	The linear regression between TSP and element concentrations	73- 74
26	Trace metals concentration emitted from paddy field fire during different combustion phases	78
27	Trace metals concentration (in % of total mass) emitted from paddy field fire during different combustion phases	78
28	TSP concentrations from the different mass of rice straw burning in closed chamber	80
29	Trace metals concentration emitted from rice straw burning in the chamber according to different mass of rice straw	82
30	Trace metals concentration (in % of total mass) emitted from rice straw burning in the chamber according to different mass of rice straw	82
31	Trace metals concentration emitted from six of 2-stroke motorcycles	87



32	Trace metals concentration (in % of total mass) emitted from six of 2-stroke motorcycles	87
33	Trace metals concentration emitted from diesel powered vehicles	88
34	Trace metals concentration (in % of total mass) emitted from diesel powered vehicles	88
35	Morphological surface of blank fiber glass filter	94
36	Haze particles collected in September 1999 with magnification of (a) X1,000; (b) X8,000	95
37	Haze particles collected during haze episode on 4 October 1997 with magnification of (a) X1,000; (b) X2,200; (c) X15,000	96-97
38	Smoke particles collected during peat swamp fire at Sepang with magnification of (a) X1,000; (b) X2,200	100
39	Smoke particles collected from 1-g of the rice straw burning with magnification of (a) X1,000; (b) X2,200	101
40	Petrol exhaust particles with magnification of (a) X1,000; (b) X2,200	103
41	Diesel exhaust particles with magnification of (a) X1,000; (b) X10,000	104



LIST OF ABBREVIATIONS

Aerodynamic Diameter	D _a
Aerosol Scattering Coefficient	B _{sp}
Air Pollutant Index	API
Atomic Absorption Spectrophotometer	AAS
Computerized Vehicular Inspection Centre	PUSPAKOM
Continuous Air Quality Monitoring	CAQM
Department of Environment	DOE
Department of Environmental Science, Universiti Putra Malaysia	JSAS
Diesel Exhaust Particles	DEP
Environmental Protection Agency	EPA
Glass microfiber filters	GMF
High Volume Sampler	HVS
Inhalable Particles	IP
Intensification of Research in Priority Area	IRPA
Malaysian Agricultural Research and Development Institute	MARDI
Malaysian Air Quality Index	MAQI
mass median diameters	MMD
National Ambient Air Quality Standards	NAAQS
Particulate matter with aerodynamic diameter less than or equal to 10 µm	PM ₁₀
Petrol Exhaust Particles	PEP
Pollutant Standard Index	PSI
Recommended Malaysian Air Quality Guideline	RMG



Respirable Particulate	RSP
standard deviation	S.D.
Suspended Particulate Matter	SPM
Total Suspended Particulate	TSP



CHAPTER I

INTRODUCTION

Atmospheric Aerosols

In recent years, there has been a growing concern about atmospheric problems, such as ozone layer depletion, acid rain and the fates of toxic chemicals in the atmosphere. These problems are affected by a wide variety of complex chemical and physical processes. Atmospheric aerosols are currently eliciting strong research interest because of their important in affecting climate, restricting visibility and causing adverse effects on human health. Monitoring of atmospheric particulate matter concentration is the fundamental to interpret the characterization of particulate matter. Current techniques used to measure the mass concentration of particles in air make use of size-specific sampling devices and thus the PM₁₀ (particles with aerodynamic diameter equal or less than 10 μm) may be determined as an index of the mass concentration of particles that can penetrate into the human thorax (WHO, 1999).

Atmospheric aerosols are recognized as important contributors to global climate change (Piketh et al., 1999; Finlayson-Pitts and Pitts, 2000). Once in the atmosphere, those compounds may influence the properties of the atmosphere since the particles can absorb, scatter and reflect solar radiation (Andreae et al., 1996; Yamasoe et al., 2000; Xu et al., 2002) and some of the emitted gases such as CO₂ and CH₄ can contribute to the greenhouse effect. The radiative effects of anthropogenic aerosols are relatively large compared to their mass contribution



because they are in the size range, which is radiatively most active (Simoneit and Elias, 2000). Light extinction by aerosols also reduces the quantity and quality of solar radiation reaching the surface, which may influence crop production (Xu et al., 2002).

The most obvious characteristic of air pollution is the loss of visibility. This is primarily due to suspended airborne particles, which are caused by the combination of ammonia with the oxidation products of atmospheric pollutants forming reflective particles of NH_4HSO_4 , $(\text{NH}_4)_2\text{SO}_4$ and NH_4NO_3 (Wellburn, 1993). Such particulate scatters light efficiently, absorb and reflect incoming solar radiation, giving the atmosphere a hazy appearance. Particles with diameters in the range 0.38-0.76 μm have comparable dimensions to the wavelength of visible radiation and will therefore affect its transmission producing haze (Fergusson, 1991). Although haze occurrences have been noted as early as the sixties, the haze episodes of September 1982, April 1983, August 1990 and September-October 1991 in Malaysia have attracted a great deal of public attention and concern (Abas and Simoneit, 1996).

Aerosol size is the major factor to determine the atmospheric behavior of aerosol particles and thereby controls the residence time and removal mechanisms of atmospheric pollutants (Bidleman, 1988). In the case of grits and most coarse dusts, only particles greater than 50 μm in diameter are visible and those less than 10 μm across remain suspended for some time and, if very small (0.1-2 μm), act as nuclei for the condensation of water during cloud formation. They are only removed as rain or when hit by falling rain (wash-out) (Wellburn, 1993).

Biomass Burning

Biomass combustion giving rise to the release of large quantities of gaseous emissions and particulate matter (Cofer III et al., 1990; Yamasoe et al., 2000; Jayaratne et al., 2001) with instantaneous and long-term effects on quality, global climate and biogeochemical distribution of nutrients. Emissions from domestic biomass burning activity, combined with adverse geographical and meteorological conditions, contribute to poor air quality in both large and small urban area around the world (Koe et al., 2001). Generally, there are several major sources of biomass burning around the world. For instance, in India, biomass burning is originated by shifting cultivation, accidental fires, controlled burning, fire wood burning, burning from agricultural residues and burning due to fire lines (Prasad et al., 2001). Combustion processes produce a wide range of particulate whose composition and morphology depend on a number of factors, such as fuel type, oxygen flow, temperature, etc. (Lim and Renberg, 1997). According to Garstang et al. (1997), the mechanisms by which the particulate smokes from biomass fires are removed from the atmosphere can be stated in order of decreasing importance:

- wet scavenging by cloud and precipitation;
- gravitational removal by sedimentation assisted by coagulation;
- dry removal by wind-driven impaction near the earth's surface.