HEALTH GUIDELINES FOR VEGETATION FIRE EVENTS

Guideline Document

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This WHO document on the *Health Guidelines for Vegetation Fire Events* is the outcome of the WHO-UNEP-WMO expert task force meeting held in Lima, Perú, in October 1998. This Guideline document is accompanied by a document with the background papers presented and discussed at the meeting and used for the preparation of these guidelines. A Teachers' Guide has also been prepared that allows the presentation of the essential contents of the Health Guidelines in a four day training course.

Note to the user: This document is the pre-publication version (not identical with the printed volume). The final electronic form of this document is available on the CD ROM of the Healthy Cities Air Management Information System AMIS and on the Web sites of the World Health Organization (http://www.who.int/peh/air/vegetation_fires.htm) and the Global Fire Monitoring Center (http://www.fire.uni-freiburg.de).

Published on behalf of

United Nations Environment Programme, Nairobi

UNEP

World Health Organization, Geneva
Cluster of Sustainable Development and Healthy Environments (SDE)
Department of Emergency and Humanitarian Action (EHA)
Department of Protection of the Human Environment (PHE)
Occupational and Environmental Health Programme (OEH)

World Meteorological Organization, Geneva
Institute of Environmental Epidemiology
Ministry of the Environment, Singapore

Published by Institute of Environmental Epidemiology, Ministry of the Environment, 40 Scotts Road #22-00, Singapore 228 231, Tel: +65 731 9754, Fax: +65 734 8287, Email: envqe@cs.goc.sg

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The authors alone are responsible for the views expressed in this document.

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Foreword

For several months in 1997-98, the smoke disaster in South-east Asia affected several countries including Brunei Darussalam, Indonesia, Malaysia, Singapore, Philippines, and Thailand, as well as tens of millions of people in the region. Authorities of these countries have taken measures to mitigate smoke effects on population health and to control forest fires. This was particularly the case for Indonesia, which officially requested UN assistance. The fires threatened to evolve into a more complex emergency, through the potential of causing voluntary or planned population movement (evacuation), and through effects on health, economy and security.

Vegetation fires, particularly uncontrolled ones, are a substantial source of air pollution in urban and rural areas. As such, they affect health delivery systems and access to health care, and add to rapid environmental change and degradation. Vegetation fires also add to urban and indoor air pollution (from domestic wood and coal burning for cooking and heating), and thus enhance the risk of acute respiratory infections in childhood, a major killer of young children in developing countries. The health of women is particularly affected from forest-fire pollution, as they are already exposed to high levels of air pollution in the home. As health is so dependent on a healthy physical environment, there is a need to address the global dimensions of the problem of forest fires. The challenge is to ensure sustainable development and healthy living conditions. And poverty, which leads to land clearing by burning, is at the center of that challenge.

These Health Guidelines are a result of the work of two departments of the WHO: the Department of Emergency and Humanitarian Action (EHA) and the Department of Protection of the Human Environment (PHE), both in the Cluster of Sustainable Development and Healthy Environment (SDE) of the WHO. The guidelines are intended:

- To develop the necessary capacity, not only at regional and national levels but also at the local level, and to give WHO’s support to local planning efforts in health, environment and sustainable development;
- To strengthen the basis for inter-sector action in sustainable development policy and planning, by providing the necessary evidence and guidance;
- To determine best practices and disseminate such knowledge worldwide, so that all may benefit and learn from them;
- To strengthen the linkages between health, environment and development;
- To provide ongoing support in the development and implementation of the Regional and National Haze Action Plans, as parts of Environmental Action Plans to be integrated into national sustainable development planning efforts;
- To ensure that the health components of Agenda 21 of the United Nations Programme of Action, following the Earth Summit in Rio de Janeiro, are adequately addressed so that health gains trigger economies to grow and, subsequently, poverty to decrease.

Agenda 21 states:

In many locations around the world the general environment (air, water and land), workplaces and even individual dwellings are so badly polluted that the health of hundreds of millions of people is adversely affected. This is, inter alia, due to past and present developments in consumption and production patterns and lifestyles, in energy production and use, in industry, in transportation etc., with little or no regard for environmental protection. There have been notable improvements in some countries, but deterioration of the environment continues. The ability of countries to tackle pollution and health problems is greatly restrained because of lack of resources. Pollution control and health protection measures have often not kept pace with economic development.

Forests worldwide have been and are being threatened by uncontrolled degradation and conversion to other types of land uses, influenced by increasing human needs; agricultural expansion; and environmentally harmful mismanagement, including, for example, lack of adequate forest-fire control and anti-poaching measures, unsustainable commercial logging, overgrazing and unregulated browsing, harmful effects of airborne pollutants, economic incentives and other measures taken by other sectors of the economy.

Concern about climate change and climate variability, air pollution and ozone depletion has created new demands for scientific, economic and social information to reduce the remaining uncertainties in these fields. Better understanding and prediction of the various properties of the atmosphere and of the affected ecosystems, as well as health impacts and their interactions with socio-economic factors, are needed.

To some extent, many countries have already established policies, legislation and emergency response measures to control and combat vegetation fires and air pollution, and to minimize their impacts. For this reason, the development of a common set of Health Guidelines for the interest of all the countries involved is most timely. To ensure that the objectives of these Guidelines can be achieved, it is important to help the respective countries include the Guidelines in their existing policy, legislation and emergency response. This will allow areas of inadequacy to be identified and strengthened.

These guidelines help to greatly reduce the burden of excess mortality and preventable disability suffered by the poor. They also counter potential threats to health resulting from economic crises, unhealthy environments and risky behaviour. In this sense, the guidelines contribute to meeting two of the key challenges that were highlighted in the 1999 World Health Report and, thus, they contribute to making health a fundamental human right.

Dietrich Schwela

Preface

Smoke pollution due to vegetation fire events is an important public health issue and involves major risks for the health of the people and the environment. Vegetation fires in Asia, Latin America, Africa, and other parts of the world are recurring phenomena. They often lead to health impacts such as increased mortality, increased hospital admissions due to respiratory and cardiovascular diseases, and increased emergency room and outpatient visits. Smoke from vegetation fires sometimes even overlies urban air pollution, and exposure levels are intermediate between ambient air pollution and indoor air pollution from domestic cooking and heating. Because the effects of fire events are nation- and region-wide, a "natural" disaster can evolve into a more complex emergency, both through population movement and through its effects on the economy and security of the affected countries. In such an emergency the development of an early warning system would involve the multidisciplinary collaboration of scientists, technicians and administrators.

The following guidelines were developed in a collaboration of the Department of Emergency and Humanitarian Action (EHA) and the Department of Protection of Human Environment (PHE), both in the Cluster of Sustainable Development and Healthy Environment (SDE) of WHO. As an outcome of this fruitful collaboration, WHO is issuing this set of materials to provide operational tools for health care and environmental professionals, public health authorities, manufacturers of health care products and policy makers.

This WHO document *Health Guidelines for Vegetation Fire Events – Guideline document* is a comprehensive handbook with the objective of providing guidance to Governments and authorities from municipalities on the action to be taken in vegetation fire events, when large parts of the population are exposed to smoke from fires. It has to be seen as the main document that summarises the experience and knowledge laid down in the background papers presented at the WHO-UNEP-WMO expert meeting in Lima, Perú, 3-6 October 1998. These background papers are published separately in the document *Health Guidelines for Vegetation Fire Events - Background Papers*. A third document entitled *Health Guidelines for Vegetation Fire Events – Teachers' Guide* compiles educational materials that can be used in training courses on the Health Guidelines for Vegetation Fire Events.

All three publications form a "set", which can be useful for handling this important public health issue in a practical manner. These are the first WHO publications providing global advice and guidance on the management of vegetation fire events.

The set of documents on the Health Guidelines for Vegetation Fire Events (Guidelines, Background Papers and Teachers' Guide) aims to achieve the following objectives:

- To raise awareness on public health and environment issues;
- To provide information, including an early warning system, on how to prevent the health impacts of vegetation fire events;
- To identify efficient, sustainable, economic and culturally acceptable prevention practices;

This *Guideline document* has been prepared as a practical response to the need for action both with respect to the recurrent vegetation fires at the local level, and improved legislation, management and guidance at the national and regional levels. WHO will be pleased to see that these guidelines are used widely. Continuing efforts will be made to improve its content and structure. It would be appreciated if the users of this guideline would provide feedback from its use and their own experiences. Please send your comments and suggestions on the WHO *Health Guidelines for Vegetation Fire Events – Guideline document* directly to the Department of the Protection of the Human Environment, Occupational and Environmental Health, World Health Organization, Geneva, Switzerland (Fax: +41 22-791 4127, e-mail: schwelad@who.int).

Acknowledgements

The World Health Organization thanks all individuals who have contributed to the preparation of this document *Health Guidelines for Vegetation Fire Events – Guideline Document*. The international, multidisciplinary group of contributors to and reviewers of the Health guidelines are listed in the "Participant list" section of the Health Guidelines in Annex K. Special thanks are due to the chairpersons of the WHO-UNEP-WMO expert task force meeting held in Lima, Perú, in October 1998: The conference chair Dr Johann G. Goldammer, Max Planck Institut for Chemistry/Global Fire Monitoring Center, and the chairpersons of the two working groups, Dr Michael Brauer, University of British Columbia, and Dr Joel Levine, NASA Langley Research Center. Special contribution are gratefully acknowledged to those who provided the background papers and to those who contributed to the success of the WHO-UNEP-WMO expert meeting:

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Dr Celso Bambarén, Ministerio de Salud, Lima, Perú
Dr Michael Brauer, University of British Columbia, Vancouver, Canada;
Ing. Harold Cáceres Deza, Lima, Perú;
Mr Sergio Caporali, Pan American Center for Sanitary Engineering and Environmental Sciences, CEPIS, Lima, Perú;
Mr Hashim Daud, Department of Environment, Kuala Lumpur, Malaysia;
Mr Yudanarso Dawud, Persahabatan Hospital, Jakarta Timur, Indonesia;
Dr Michael Garstang, University of Virginia, Carlottesville, VA, USA;
Dr Goh Kee Tai, Ministry of the Environment, Singapore;
Professor Dr Johann G. Goldammer, Max Planck Institute for Chemistry, Freiburg, Germany;
Dr Hiremagalur N. B. Gopalan, United Nations Environment Programme, Nairobi, Kenya;
Dr William B. Grant, NASA Langley Research Center, Hampton, VA, USA;
Ms. Angelika Heil, GTY and Ministry of Forestry and Estate Crops, Indonesia;
Dr Mauricio Ilabaca Marileo, Ministerio de Salud, Santiago de Chile;
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Mr Roy A. Johnson, Department of Interior, Boise, ID, USA;
Dr Yoram Kaufman, NASA Goddard Space Flight Center, Greenbelt, MD, USA;
Dr Etsuko Kita, World Health Organization, Geneva, Switzerland;
Dr Marcelo Korc, Pan American Center for Sanitary Engineering and Environmental Sciences, CEPIS, Lima, Perú;
Dr Osamu Kunii, International Medical Center of Japan, Tokyo, Japan;
Dr Arlene S. Levine, NASA Langley Rersearch Center, Hampton, VA, USA;
Dr Joel S. Levine, NASA Langley Research Center, Hampton, VA, USA;
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Dr Ooi Peng Lim, Ministry of the Environment, Singapore;
Dr Kanchanasak Phonboon, Health Systems Research Institute, Bangkok, Thailand;

Dr Joseph P. Pinto, US Environmental Protection Agency, Research Triangle Park, NC, USA;
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Dr J. Hernán Ulloa-Pinto, 3M, Bogota, Colombia
Dr Claude de Ville de Goyet, Pan American Health Organization, Washington, DC, USA;
Dr Darold E. Ward, US Department of Agriculture - Forest Service, Missoula, MT, USA;
Dr Paulus Angus Winarso, Meteorological and Geophysical Agency, Jakarta, Indonesia.

Particular thanks are due to the Ministry of Health of Japan, which provided ample funding to convene the WHO-UNEP-WMO expert task force meeting in Lima, Perú, in October 1998 to produce the Health Guidelines for Vegetation Fire Events including the Guideline document, the background papers document and the Teachers' Guide. Moreover, this funding could be used to convene two training courses on the Health Guidelines, the first one in Kuala Lumpur, Malaysia in December 1998, and the second one in Brasilia, Brazil, in May 1999.

The contributions of the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in co-sponsoring the expert task force meeting on the Health Guidelines are gratefully acknowledged.

Executive Summary

Introduction

The Health Guidelines for Vegetation Fire Events are intended:

- To advise national and international authorities on how to develop and implement an early warning system to protect the health of the population exposed to air pollution caused by vegetation fire events.

- To provide support in capacity building and in the development and implementation of the Regional, National, and Local Haze Action Plans. These plans will be integrated into national sustainable development planning efforts, as parts of the Environmental Action Plans;

- To provide the necessary evidence and guidance on vegetation fires and their health impacts, to strengthen the basis for inter-sector action in sustainable development policy and planning;

- To determine best practices, and disseminate such knowledge worldwide, with the objective of strengthening our understanding of the linkages between health, environment and development.

The Health Guidelines provide decisive recommendations on how to make optimal use of the vast amount of multidisciplinary information that is available worldwide. This information includes knowledge of the global, regional and national extents of vegetation fires obtained by remote sensing techniques and characterises the sources with respect to strength and pollutants. The development of an early warning system is based on ground-base monitoring, space and climate monitoring and modelling. The Health Guidelines also provide insight into the acute and chronic health effects of air pollution due to biomass burning, advise on public advisories and mitigation measures, and provide guidance on the methodology for assessing the health impacts of vegetation fires. Important issues are the prevention of future health-affecting events through discussion of land-use and fire policies, and recommendations on scientific work to be performed in the future in order to implement the early warning system.

Fires in forests and other vegetation produce gas and particle emissions that have impacts on the composition of the global atmosphere. These emissions interact with those from fossil-fuel combustion and other technological sources which are the major causes of urban air pollution. Smoke emissions from wildland fires cause visibility problems which may result in accidents and economic losses. Smoke generated by wildland fires may also affect human health and lead to loss of human lives. The development of policies and guidelines for reducing the health impacts of smoke from burning vegetation must be linked with policies which address the smoke problem at its source. Therefore, the Health Guidelines help to greatly reduce the burden of excess mortality and preventable disability suffered particularly by the poor. With this in mind, the Health Guidelines implement health gains that, in turn, trigger economies to grow and poverty to be cut.

Early warning systems of fire and atmospheric pollution are essential components of fire and smoke management. They may involve locally generated indicators, such as fire-weather forecasts and assessment of vegetation dryness. Advanced technologies for detection and monitoring of fires, however, rely on remotely sensed data, evaluation of synoptic weather information, modelling capabilities of fire occurrence and behaviour, and international communication systems. These data are integrated and processed with other relevant information, such as the population at risk, and disseminated in fire information systems.

Emission, transport of air pollutants and exposure

Wildfires (uncontrolled fires) are common in all vegetation zones. They are mostly caused by negligence and are often associated with escaped land-use fires. Biomass burning is a major contributor of toxic gaseous and particle air pollutants, as well as greenhouse and reactive gases and occurs throughout the world. But unlike some anthropogenic sources, it is poorly quantified. The nature of biomass burning is such that the combustion is not complete, and as a result a large number of pollutants are emitted. Among the air pollutants emitted from biomass fires are widespread pollutants such as particulate matter, oxides of nitrogen, sulphur dioxide, and carbon monoxide. After the emission, during transport, the air pollutants undergo transformation processes, which result in physico-chemical changes of the pollutants.

In general, comprehensive approaches to be standardized for use in dealing with potential risks to public health of emissions from biomass fires should include:

- Characterization of the magnitude and composition of the emissions and their transformations during transport;
- Quantification of resulting concentrations of ambient air pollutants in populated areas;
- Evaluation of likely exposure scenarios for affected populations (both indoors and outdoors);
- Assessment of consequent health risks posed by such human exposures.

When considering exposure to smoke plumes from biomass burning, particles receive the most attention of all air pollutants that have potentially detrimental health effects. Very small airborne particles (aerodynamic diameters below 2.5 μm) are considered the most significant pollutants from the point of view of health effects. These particles have a very high probability of deposition in deeper parts of the human respiratory tract, where they may lead to a range of health impacts by virtue of their physical, chemical, toxicological or carcinogenic nature.

Ground-based monitoring

Ground-based air quality monitoring and remote sensing through satellite imagery can assess air pollutant concentrations of smoke caused by vegetation fires. Ground-based air quality monitoring should aim to provide information for public health warning and decision making on protective measures, for dispersion model inputs, verification and development, and for human health studies that evaluate effects of smoke. Air quality monitoring should be conducted on a regular basis in major urban and other populated areas likely to be impacted by biomass burning. In addition, stations should be located in rural areas, for background concentration information. Existing networks should be reviewed and the best sites for monitoring smoke and haze episodes identified. Establishment of additional monitoring stations in areas not covered by the existing networks should be considered. The location of the sites should be determined in accordance with existing guidelines. A ground-based network of air samplers is necessary to measure the concentration of aerosols for sizes under 2.5 μm in diameter.

In measured compounds efforts should be made to separate the contribution of biomass burning from that of other sources. Monitoring of aerosol mass, visibility, meteorological parameters, optical depth and solar radiation are of highest priority. At selected sites, targeted chemical quantities such as carbon monoxide, ozone, nitrogen oxides, sulphur dioxide, carbon dioxide, ultraviolet radiation, aldehydes and other trace pollutants should be measured.

Formulation of uniform protocols for sampling, including temporal resolution and reporting procedures, should be established. The establishment of quality assurance/quality control procedures is essential for obtaining reliable and reproducible results. National and regional databases should be established for use of data before, during and after smoke/haze episodes. These data can be used, for instance, in epidemiological studies, planning for future events and for transport modelling studies. The exchange of validated measurement data should be promoted. The different air pollution indices that are used in regional smoke and haze alerts should be harmonized.

To maximize the usefulness of data collected by different networks, participation should be encouraged in international activities such as the Global Atmosphere Watch programme of the World Meteorological Organization or the Air Management Information System of the World Health Organization.

Satellite data

Satellite data are available for monitoring fires and smoke aerosol, e.g., at the National Aeronautics and Space Administration (NASA) or the National Oceanic and Atmospheric Administration (NOAA) of the United States. Satellite imagery provides information on the dryness of the vegetation, location and size of major fires and smoke plumes, energy released by fires, and air pollutants in the smoke plumes. Additional satellite sensors delivering better data on vegetation fires will be available within the next 1-2 years. With respect to accessibility and evaluation of these data, it is recommended that a centre of excellence in fire and smoke monitoring be established. The centre should be familiar with the technology and software for analyzing satellite data. Its responsibilities would be to oversee the regional estimates of fire emissions and to validate the smoke and emission analyses of satellite data. The centre should develop new strategies for fire and smoke detection and advise the international bodies and agencies of its needs. It would also integrate ground-based, aircraft and satellite information. It would work with the regional centres in disseminating information and new technology to the regional centres, as well as coordinate the training of technicians to handle new satellite data and software.

It would also be important to establish an indicator for grading the severity of on-going fires. Such an indicator could combine satellite data on the number of active fires per unit area, size of the areas burning, energy released by the fires, the extent the smoke palls and the concentration of pollutants in them. Also recommended is the development of a space fire monitoring system, comprising fire detection satellites and real-time portable receiving hardware, to provide diurnal information on the location of active fires, smoke, and trace gases emitted from the fires. If possible, the information generated by this system should be provided directly from the satellite to local users in near real-time, in a simple and inexpensive manner.

On a regional level there is a need for fire activity centres. These centres would receive the regional satellite data using their own receiving stations, and integrate them both with meteorological information and with ground and aircraft monitoring efforts. The centres would use the data to monitor the development of the fires and smoke and predict the spread of the smoke. The centres are needed since the biomass burning changes from region to region, and since direct reception of the satellite data is essential for real time operation. As there are already WMO centres or representatives with satellite and meteorological capability, they are natural candidates for the location of the regional fire activity centres.

With respect to data availability, it is recommended that NASA and NOAA of the United States and other appropriate agencies be approached to continue placing relevant data such as aerosol and vegetation indexes on the Web. There is a need to develop software packages and instruction material for using satellite data to warn of smoke impacts and to analyse smoke concentrations. Where extensive and intense fire episodes cause severe health problems the reliability of the fire emission estimates should be ensured by continuous validation, using ground based *in situ* and remote measurements. Such validation will enhance the use of satellite data as input to the simulation model. Once developed, the software packages would also support the determination of environmental hazards for human health.

Atmospheric transport models

The distribution and concentrations of fire emissions must be calculated from atmospheric transport models. A description of the spatial and temporal distribution of fire emissions should consider the situation before, during, and after the episode. Defined goals are to be achieved in each of those three stages of the event. It is recommended that the agency capable of carrying out the complete suite of tasks associated with climate monitoring and modelling be identified in each area.

Mitigation measures

Mitigation measures recommended for acute events include remaining indoors, personal lifestyle modifications, use of air cleaners, use of masks and respirators, outdoor precautionary measures, evacuation to emergency shelters, and school and business activities. To enhance the protection offered by remaining indoors, individuals/building managers should take action to reduce the infiltration of outdoor air. Schools, childcare centres, retirement centres, nursing homes, hospitals and hospices should be especially urged to provide air conditioned rooms to susceptible individuals, and effective filters should be installed and maintained in these rooms. During severe smoke episodes, members of the public should be advised on lifestyle modifications, such as the reduction of physical activities and the restriction of cigarette smoking. Evaluation of the use of portable air cleaners should be conducted and appropriate advice given to the public, to assist them in purchasing models suitable for homes or offices. Advice should be given to the public on specific dust/mask respirator types and their relative utility for filtration of smoke particles, including the proper use and selection of available dust masks/respirators. Precautionary measures should be taken to safeguard the health and safety of workers who must continue to perform outdoor work. For example, employers should provide respirators to workers who must work outdoors during acute emergencies. In severe episodes, susceptible individuals should be allowed free access to air-conditioned emergency shelters (with adequate particle filtration). These could be located inside large commercial buildings, educational facilities or shopping malls.

Health effects

The epidemiological studies of indoor and community exposure to biomass smoke indicate a consistent relationship between exposure and increased respiratory symptoms, increased risk of respiratory illness and decreased lung function. A limited number of studies also indicate an association between biomass smoke exposure and visits to emergency departments. Recent assessments of impacts from the 1997-98 Southeast Asian haze episode support an association with increased hospital visits. Studies of the relationship between biomass air pollution and acute mortality have not been conducted to date. However, as biomass air pollution mostly consists of fine and ultra-fine particulate matter the new air quality guidelines of the WHO for particulate matter suggest a definite impact on daily mortality, hospital admissions, emergency department visits and outpatient visits.

The health effects of long-term inhalation of smoke generated by biomass burning (“biomass smoke”) have been documented in developing countries where women spend many hours cooking over non-vented indoor stoves. These studies indicate that biomass smoke exposure is associated with the development of chronic lung disease in adults, although these exposures are much higher than would occur as a result of short-term exposure to biomass air pollution associated with vegetation fires. These studies do indicate the serious consequences of exposure to high levels of biomass air pollution. The limited data on biomass smoke and cancer do not indicate an increased risk even at very high levels of exposure. This evidence includes studies of long-term exposure to high levels of biomass smoke from domestic cooking in developing countries. While biomass smoke clearly is potentially carcinogenic, it is much less so than motor vehicle exhaust.

Assessing the health effects of smoke from vegetation fires is a difficult task. Critical factors in ascertaining the health effects of air pollution include: characteristics of the pollutants, population exposure, individual exposure, susceptibility of the exposed individual, potential confounding factors, and the range of health effects being studied. The availability of data on these factors greatly affects the type of study that might be undertaken. Types of study designs in air pollution epidemiology vary widely and include: short-term controlled exposure studies (chamber studies), short-term exposure studies, and long-term exposure studies. The latter two designs reflect a typical epidemiological approach to the problem of air pollution exposure. Any type of study requires careful planning of the design, implementation and analysis. During an emergency there may be a need to conduct a rapid epidemiological assessment, focusing on the demographics and health concerns of people in the affected community.

An important component of a public health plan to deal with pollution-related exposure is a surveillance system for monitoring respiratory or cardiovascular diseases. While many countries have such a system in place for infectious diseases, very few have a similar system in place for noninfectious diseases. With the increasing numbers of computerized clinical databases, however, it may be possible to set up a surveillance system for diseases that would be affected by fire-related air pollutants. Before a fire emergency a health department could, potentially, set up a surveillance system looking for chronic cardio-respiratory diseases. If this was in place, changes in these diseases could be assessed during a fire episode. In the absence of such a surveillance system, it is unlikely that any active surveillance would provide reliable information that a public health department could act on. After a fire episode several research designs, as noted above, are available to health departments who want to determine what health effects the fire episode had and who want to use the data to shape future policy.

Public policies

Policy objectives

In terms of policies, most countries have in place some form of laws and regulations for the control of forest fire and air pollution, and for protecting public health and the environment from the impact of haze episodes. Presently, areas of weakness need to be identified and means of strengthening enforcement need to be established.

With regards to *Policy Objectives*, the elements to be considered are:

- To prevent and control land and forest fires;
- To safeguard public health and safety in such an occurrence;
- To prohibit open burning;
- To introduce and implement ambient air quality guidelines and standards;
- To strengthen control on emissions from mobile and stationary sources.

The elements with respect to *Policy on Development* are:

- To set land use planning based on a sustainable development principle;
- To protect communities and ecosystems at risk from fire and haze effects.

The elements with respect to *Policy on Assessment* include:

- To monitor and report on air quality;
- To develop an effective mechanism for monitoring land and forest fires;

- To develop the capability for detecting and predicting forest fires and haze;
- To monitor the health and environmental impacts of haze.

The *Management Policies* focus on the following aspects:

- To provide the public and the authorities with information on air quality and action to be taken;
- To advise the public on action to be taken for health protection;
- To ensure medical facilities and health supplies for mitigating health impacts;
- To provide support to countries in need and to promote cooperation among countries;
- To minimize haze pollution from fuel burning;
- To strengthen the capabilities of relevant agencies;
- To strengthen interagency cooperation and support.

The success of any policy, action plan, or response mechanism will rest on the timely exchange of data, information and experiences among various national, regional, and international authorities or centres of excellence, and on their close co-operation and continuing support. Institutional arrangements at international and regional levels need to be developed and used. Early warning capability is invaluable to national authorities trying to enforce strict controls on both controlled and open burning of vegetation, crops, forest, and any form of biomass or waste. During a fire, national authorities should consult competent international bodies for advice. These international bodies should investigate the feasibility of establishing an ongoing panel of experts on haze, whose members are linked via electronic media for the rapid exchange of data and information.

Among the critical components of national governments' efforts to manage vegetation fires is the education of the population regarding the potential health impacts of air pollution produced in vegetation fires. These education efforts must occur both prior to, and during, fires to keep the population informed.

National Haze Action Plans

To ensure full preparedness of the population for the health impacts of vegetation fire pollution, a comprehensive National Haze Action Plan should be developed and widely publicized through the media, before the occurrence of any air pollution episode. Based on this action plan, government departments should develop operating procedures and ensure that the population will be aware of any changes made to public services and facilities in an emergency situation. Data on air pollution related illnesses from primary health care providers, hospitals, and mortality registries should be reported periodically. Special educational efforts should be developed for susceptible populations, such as asthmatics, the elderly, and children to ensure that they are adequately prepared for air pollution episodes. Health authorities, via the media, should proactively address frequently asked questions, such as the safety of food and potable water supplies exposed to smoke for prolonged periods.

Lessons learned from the 1997-98 fires

In reviewing the 1997-98 fire and smoke episodes, the Food and Agriculture Organization (FAO) of the United Nations evaluated those public policies which affect forest fires. The expert consultation concluded that there is a need for reliable national, regional and global systems for fire reporting and for analysis and storage of data. Such data, and information on fire causes and socio-economic and environmental effects, are required as a sound basis for policy making. Linked to these is the requirement for international agreement on terms and definitions, as a basis for information sharing and communication. Information on resource management alternatives and their consequences is essential for involvement of all stakeholders in policy formulation and development.

No single formula can cover the wide range of ecological, socio-economic, and cultural conditions that exist between and within regions, nor cover the different objectives that different societies will decide. Certain broad principles exist, however, that are common to all situations and objectives. These principles include the following:

- The formulation of national and regional policies specifically addressing forest fires, as an integral component of land-use policies, where they previously did not exist.

- Flexibility in policy implementation, and the capability of reviewing and revising fire-related policies

- Clear and measurable policy objectives and implementation strategies are needed to minimise the many adverse effects of uncontrolled fires, and to maximise the benefits from fire prevention, or from the controlled use of fire. Such objectives and implementation strategies would provide for sustainable land use practices, compatible inter-sector policies, joint fire management responsibilities at the community level, and the participation of the private sector and non-governmental organizations. Decision makers should recognize that sustainable land management may, in many instances, be attained only through the devolution of the control of forest resources, and through the involvement of communities, adjacent to or within the forest, in all aspects of management and fire protection. Land-use policies may also have to consider the need for appropriate incentives and subsidies to promote fire prevention.

- A favourable policy environment must be created for all aspects of systematic fire management (prevention, detection, suppression, prescribed fire, post-fire rehabilitation etc.) and for an appropriate balance among individual system components. Such an environment should attempt to quantify the monetary and non-market values, to emphasise the costs and benefits to society and to decision-makers.

- Policies that tend to increase forest fires must consider public health effects. Policies concerned with maintaining the health of fire-adapted ecosystems may have to balance public health and forest health issues.

Continued and improved collaboration and co-ordination are urged among the many organizations involved in forest fire-related activities at global and regional levels. Transboundary or regional agreements for collaboration in fire management need to be developed, with the technical and financial support of international organizations. International organizations, in close collaboration with the fire science community and end-users, are further urged to support the design and implementation of a global fire inventory or reporting system, to increase preparedness and responsiveness to fire outbreaks at national, regional and global levels. International organisations should play a catalytic role in the establishment of networks, to promote the sharing of information and technical co-operation among developing and developed countries. Sufficient resources should be allocated for these purposes.

Accumulated experience should not be neglected, and local indigenous knowledge and customs should be acquired from traditional fire related cultures as a guide for fire management practices and policies. Evaluation systems should be developed to assess fire damage and benefits, and to draw attention to the true costs and benefits of fires. Policies and techniques that aim to increase agricultural productivity, while providing and enforcing disincentives for reckless programmes, will slow forest conversion for unsustainable agriculture and will thus reduce forest fire damage.

Research needs

Some technical aspects may support policy formulation and implementation. They include systematic or integrated fire management; institutional co-operation; restoration/rehabilitation; and technology/research/information. New technologies offer the means to introduce new and more environmentally and socially acceptable land use management policies; particular attention is drawn to “zero-burning” land clearing techniques. Fire research at national and regional levels needs to be strengthened, to support development of fire policies and fire management capabilities, especially related to investigations into socio-economic and cultural aspects of fire outbreaks. Fire research is needed into a number of topics including:

- The development of dedicated space-borne remote sensing technologies for improving decision support in fire management, including technologies for fire detection and early warning;

- Post-fire recovery techniques, fire effects and ecosystem recovery processes;

- The impact of climate change on fire regimes and fire severity;

- The implementation of a global vegetation fire inventory, and the implementation of a center to monitor, archive, and disseminate global fire information, as well as forecast fire and related hazards;

- Special attention to fire-generated radioactive emissions;

- The development of source information for fires in different ecosystems;

- Physical/chemical factors contributing to the changes that occur over time and space during transport;

- Compilation of information pertaining to levels of exposure and fire activity, in conjunction with past fire and smoke episodes;
- Mitigation approaches;
- Health impacts of air pollution due to biomass burning within the general population.

Conclusions

Vegetation fires, particularly uncontrolled ones, are a substantial source of air pollution in urban and rural areas. They add to urban and indoor air pollution (from domestic wood and coal burning for cooking and heating). Inhaling the smoke from vegetation fires enhances the risk of acute respiratory infections in childhood, a major killer of young children in developing countries. The health of women is also particularly affected as women are already exposed to high levels of air pollution in the home environment and they suffer more from this additional burden of pollution caused by vegetation fires. Land clearing practices through vegetation fires add to rapid environmental changes and degradation. The use of forest fires for land clearing is also a consequence of poverty. Combating poverty is the central challenge to ensure sustainable development and healthy living conditions. As health is so dependent on environment, there is a need to address the global dimensions of the problem of forest fires.

vegetation fire events are an important public health issue since they involve major risks for the health of the people and the environment. Because of their nation- and region-wide effects, vegetation fire events can evolve from a sort of “natural” disaster into a more complex emergency because of population movement, and through their effects on the economy and security of the affected countries. In view of the character of a potentially complex emergency from vegetation fire events, the development of an early warning system for such events involves the collaboration of multidisciplinary groups of scientists, technicians and administrators. The Health guidelines provide the knowledge for implementing an early warning system to protect human health from the impacts of smoke and haze from vegetation fires and, therefore, help governments to cope with the recurring events.

These Health Guidelines are a result of the work of two departments of the WHO: the Department of Emergency and Humanitarian Action (EHA) and the Department of Protection of the Human Environment (PHE), both in the Cluster of Sustainable Development and Healthy Environment (SDE). The recommendations and chapters were drafted at the WHO-UNEP-WMO expert meeting held in Lima, Perú, in October 1998.

The Health Guidelines are intended to develop the necessary capacity not only at regional and national levels, but also at local levels, and to give WHO’s support to the local health, environmental and sustainable development planning efforts being undertaken; to provide the necessary evidence and guidance for strengthening inter-sector action in sustainable development policy and planning; to determine best practices, and disseminate such knowledge worldwide; to strengthen the linkages between health, environment and development; and to provide ongoing support in the development and implementation of the

Regional and National Haze Action Plans, as part of Environmental Action Plans to be integrated into national sustainable development efforts.

The Health Guidelines for Vegetation Fire Events help to ensure that the health components of Agenda 21 of the United Nations Programme of Action, following the Earth Summit in Rio de Janeiro, are adequately addressed.

1. INTRODUCTION

Wildfires and application of fire in land-use systems annually affect several hundred million hectares of forest and vegetation of the world. In some ecosystems fires play an ecologically significant role in maintaining biogeochemical cycles. In other ecosystems fires lead to the destruction of forests or to long-term site degradation. Fires in forests and other vegetation produce gas and particle emissions that affect the composition and functioning of the global atmosphere. These emissions interact with those from fossil-fuel combustion and other technological sources, which are the major causes of anthropogenic climate forcing. Smoke emissions from wildland fires also cause visibility problems which may result in accidents and economic losses, and may also affect human health and lead to loss of human lives.

In most areas of the world wildfires burning under extreme weather conditions have detrimental impacts on economies, human health and safety, with consequences comparable in severity to other major natural hazards. Unlike the majority of the geological and hydro-meteorological hazards, however, vegetation fires represent a natural and human-caused hazard which can be predicted, controlled and, in many cases, prevented through the application of appropriate policies. The development of policies and guidelines to reduce the health impacts of smoke generated from burning vegetation must be linked with policies that address the smoke problem at its source.

The objectives of fire-related policies, e.g. land-use policies, and fire management strategies, are to reduce the detrimental impacts of fire and to manage the beneficial effects of fire. They must address a broad range of elements and sectors of society, natural resources and environmental management, and technology development. Fire policies and strategies cannot be generalized, owing to the multidimensional effects of fire in the different vegetation zones and ecosystems, and to the manifold cultural, social, and economic factors involved. However, the general characteristics of large fires can be derived by combining climatological data with the historical record of large fires that produced health- and life-threatening levels of emissions. Regional impacts, including the extent, direction and particle concentration of smoke plumes from the fires, provide the background for emergency planning and the design of monitoring networks.

Early warning systems are essential components of fire and smoke management. They rely on: an evaluation of vegetation dryness and weather; the detection and monitoring of active fires; the integration and processing of these data in fire information systems with other relevant information, e.g. vegetation cover and values at risk; the modelling capabilities of fire occurrence and behaviour; and, finally, dissemination of information. Early warning of fire and atmospheric pollution hazard may involve locally generated indicators, such as local fire-weather forecasts and assessment of vegetation dryness. Advanced technologies, however, which rely on remotely sensed data, evaluation of synoptic weather information and international communication systems are now also available for remote locations.

These Health Guidelines for Vegetation Fire Events are organised as follows: In Chapter 2 air pollution generated by vegetation fires is discussed with respect to the global occurrence of recent major fires. The sources and their emissions are presented, including transformations of air pollutant during transport and exposure levels. Exposure levels can be determined through ground-based monitoring and remote sensing with satellite imagery. Space and climate monitoring and modelling of the distribution of fire products before, during and after a major fire event are discussed. This chapter is rounded out by emergency response procedures and recommendations on how to use the Health Guidelines in pre-event, during-event and post-event action.

Chapter 3 deals with the acute and chronic health effects of smoke from biomass burning and on the acute health effects of particulate matter. Public advisories are given to inform on the ambient air quality, national action and health effects, as well as cautionary statements. Mitigation measures include remaining indoors, personal lifestyle modification, use of air cleaners, use of masks and respirators, outdoor precautionary measures and evacuation to emergency shelters. The sections on public advisories and mitigation measures end with clear recommendations to authorities. Guidance is also given with the methodology for assessing the health impacts of vegetation fire. The application of the WHO Guidelines for Air Quality in episodic situations is also discussed.

Chapter 4 deals with the prevention of future health-affecting fire events. The problem of prevention can be resolved through appropriate land-use practice and fire policies. Policy objectives, policies on development, assessment and management, and National Haze Action Plans are noted as a suitable means for prevention, and the lessons learned from previous fires are demonstrated. Finally, scientific and technical research needs are pointed out.

Extensive bibliographical references are compiled in Annex A. The acronyms used in this document are collected in Annex B. Annex C presents an extensive glossary of terms to make the text better understandable. Annex D is devoted to a draft report from the ad hoc Group on the Long-range Transport and Dispersion Model Verification Database. Annex E reprints the Guidelines on Fire Management in Tropical Forest of the International Tropical Timber Organization. Annexes F, Annex G, and Annex H refer to recent seminars and workshops of the FAO/UNECE/ILO, the WMO and the WHO, relating vegetation fires to climate change, regional transport and health impacts, respectively. Early warning for fire and other enviornmental hazards was the topic of an international workshop convened on behalf of the United Nations International Decade for Natural Disaster Reduction, the results of which are presented in Annex I. Annex J presents the Global Fire Monitoring Center established recently in the University of Freiburg, Germany. The members of the WHO Expert Task Force on the Health Guidelines for Vegetation Fire Events are named in Annex K. The international programmes of the WMO (Global Atmosphere Watch) and WHO (Air Management Information System) are introduced in Annex L.

2. AIR POLLUTION FROM VEGETATION FIRES AND HEALTH

2.1 INTRODUCTION

2.1.1 GLOBAL FIRE OCCURRENCE: STATISTICS, RECENT MAJOR FIRE EVENTS AND FIRE LOSSES

Reliable statistical data on occurrence of wildland fires, areas burned and losses incurred are available for only a limited number of nations and regions. Within the northern hemisphere the most complete data set on forest fires is periodically collected and published for the member states of the United Nations Economic Commission for Europe (UNECE). It includes all Western and Eastern European countries, countries of the former Soviet Union, the U.S.A. and Canada. The last data set covers the period 1994-96 (UNECE/FAO, 1998). The data set, however, is restricted to forest fires; thus it does not include prescribed burning in agriculture and pasture systems, which is also a major source of smoke.

Other countries from outside the UNECE/EU region report fire statistics in the pages of International Forest Fire News. These statistical data are currently updated at the Global Fire Monitoring Center (GFMC), established recently in Freiburg, Germany, in the frame of the first phase of a global inventory on vegetation fires (GFMC, 1999a).

A global data set of fire activities has been developed on the basis of active fires detected by the Advanced Very High-Resolution Radiometer (AVHRR) sensor of the National Oceanic and Atmospheric Administration (NOAA) of the United States. This data set provides the temporal and spatial distribution of vegetation fires throughout the year. It does not provide, however, a quantitative database in terms of area burned, vegetative matter combusted, and gas and particle emissions generated. Space borne sensors have been used in a large number of case studies to determine land areas affected and emissions produced by fires. Thus, potential tools for a quantitative inventory of fire effects using space borne sensors are available.

The following information is partially taken from the GFMC database, the Report "Fire and Related Environmental Hazards" of the UN International Decade for Natural Disaster Reduction (IDNDR) Early Warning Programme (Goldammer, 1997), and the draft study on "Public Policies Affecting Forest Fires, Europe and Temperate-Boreal Asia" of the Food and Agriculture Organization (FAO) of the United Nations (Goldammer, 1999).

Main vegetation types affected by fire:

Wildfires (uncontrolled fires) are common in all vegetation zones. They are mostly caused by negligence and are often associated with escaped land-use fires. The following types of vegetation burning generate smoke, which may affect public health:

- Wildfires (uncontrolled fires) in forests
- Burning of tropical grass, brush and tree savannahs
- Conversion of forest and brushland to plantations, agricultural and pastoral systems
- Burning of agricultural residues, control of bush and weeds on grazing and croplands

- Prescribed burning in forestry

Wildfires (uncontrolled fires) in forests:

In the temperate and northern boreal forests wildfires occur regularly during the dry northern summers. In North America and Eurasia between 5 and 20 million hectares are burned annually. In the less populated high latitudes the ignition sources are dominated by lightning, while in more frequently populated regions humans become the dominating fire cause. In the Mediterranean region an average of ca. 0.6 million hectares of forest and other land is burned annually.

The equatorial rainforests are usually too moist to allow the propagation of wildfires. However, extreme droughts in association with forest exploitation periodically create conditions of flammability, fuel availability and fire spread in the equatorial rain forests. Such events regularly occur in the forests of tropical South East Asia. They are related to cyclic climatic fluctuations, triggered by the El Niño-Southern Oscillation (ENSO) phenomenon. Some examples of large-scale (catastrophic) fire events are given below. The largest areas affected by uncontrolled wildfires in tropical forests are in the seasonal forest biomes (deciduous and semi-deciduous forests, sometimes also referred to as "monsoon" forests). Here, the fires burn in short return intervals of 1 to 3 years. The tropical sub-mountain coniferous forests (pine forests) are also subjected to regular fires.

Burning of tropical grass, brush and tree savannahs:

Tropical savannahs cover an area of about 2,300-2,600 million hectares worldwide. Savannahs typically consist of a more or less continuous layer of grass with interspersed trees and shrubs. There are numerous transition types between savannahs and open forests. The surface fuels in these ecosystems are dominated by grasses and leaves shed during the dry season, and burn periodically at intervals ranging from one to four years. Fire frequency has increased in some regions as a result of increasing population and more intensive use of rangeland. The area of savannahs potentially subjected to fire each year is up to several hundred million hectares. As a result, savannah burning releases about three times as much gas and particle emissions to the atmosphere as deforestation burning. It is estimated that more than 3,000 million metric tons of vegetative matter are burned in tropical savannahs annually.

Conversion of forest and brushland to plantations, agricultural and pastoral systems:

Two types of forest clearing are commonly used for conversion to agricultural purposes, predominantly in the tropics: shifting agriculture, practised notably by farmers, and permanent removal of forest. In shifting agriculture, which is practised by several hundred million people worldwide, the cleared areas are used for agriculture for a few years until yields decline, and then are abandoned and new areas cleared. Old areas are allowed to return to forest vegetation. The generally observed shortening of shifting agriculture cycles is increasingly associated with site degradation and makes this traditional land-use technique one of the leading causes of global tropical deforestation. Permanent removal of forest aims to convert it to grazing or crop lands. In both instances, the clearing and burning follows initially the same pattern: trees are felled at the end of the wet season. After extraction of marketable and useable trees, the vegetation is left to dry to obtain better burning efficiency.

The conversion of primary or secondary forest into permanent agriculture and grazing land, including tree plantations, is driven by expanding human populations that require additional food and living space, but also by large-scale resettlement programmes and land speculation. The net amount of plant biomass, which is combusted in the process of vegetation clearing, is in the range of 1 to 2 billion metric tons.

Burning of agricultural residues, control of bush and weeds on grazing and croplands:

A substantial amount of agricultural residues, e.g. straw and stalks, is disposed of by burning. The magnitude of this practice is extremely difficult to quantify because of its distributed nature. No statistics are available, mostly because material of direct economic value is not involved. It has been estimated that between 800 and 1,200 million metric tons of agricultural residuals are burned annually, making this practice a major source of atmospheric pollution, mainly in the tropics. By tradition fire is also a common practice to control bush and weed encroachment on grazing and croplands.

Prescribed burning in forestry:

Prescribed fires are a commonly used tool of forest management, particularly in North America and Australia. They serve to reduce the accumulation of dry, combustible plant debris, a major cause of destructive wildfires. They are also used to eliminate shrubby vegetation, which competes with tree crops for nutrients. In North America, about 2 million hectares are burned annually by prescribed fires. Figures from Australia show 40-130 million hectares are burned annually.

Prescribed burning for stabilising tropical aforestations of pines and eucalyptus is becoming of increasing interest. Due to the lighter fuel loads associated with understorey burning, the amount of vegetative matter burned per hectare is relatively small.

Seasonality of fire use and wildfires

Frequent mention is made in the literature of "burning seasons" and it is often assumed that practically no burning takes place outside of these periods. Indeed, a large fraction of the burning of forests and savannahs does take place during the dry season, and therefore burning is most intensive in the northern hemisphere from November to March and in the southern hemisphere from June to September. However, experience in tropical countries shows that burning can be observed almost whenever and wherever there is plant material dry enough to burn. This applies not only to cooking and heating fires, but also to burning of garden and agricultural wastes, burning of the areas surrounding living quarters to control insects, weeds, snakes, etc., and often burning just for the pleasure of watching the flames and smoke. By the end of the rainy season, many farmers are waiting for cleared areas to become dry enough to burn, leading to an outbreak of burning in late May and early June in the southern-hemispheric part of Brazil. The large-scale forest clearing burns are usually started later in the dry season in order to have drier fuel and a better combustion efficiency (to be defined later).

Recent major fire episodes and losses

Comprehensive reports with final data on losses caused by forest and other vegetation fires (wildland fires), including impacts on human health, are only occasionally available. The main reason for the lack of reliable data is that the majority of both the benefits and losses from wildland fires involve intangible non-use values or non-market outputs and do not have a common base for comparison, e.g. bio-diversity, ecosystem functioning, erosion, etc. Market values, such as loss of timber or tourism activity, have been calculated in some cases.

- The large wildfires in Borneo during the ENSO drought of 1982-83 burned more than 5 million hectares of forest and agricultural lands. Loss of timber values of ca. US$ 8.3 billion, and a total of timber and non-timber values and rehabilitation costs of US$ 9.075 billion

- First assessment of damages caused by the fire episode of 1997-98 in Indonesia on 4-5 million ha: US$ 4.5 billion (short-term health damages; loss of industrial production, tourism, air, ground and maritime transportation; fishing decline; cloud seeding and fire-fighting costs; losses of agricultural products, and timber; and direct and indirect forest benefits; EEPSEA, 1998). Most recent evaluation of satellite imaging reveals that on the Indonesian islands of Sumatra and Kalimantan (Borneo) ca. 9 million hectares of vegetation were burned in 1997-98.

- The fires burning in Mexico during the 1998 episode forced the local government to shut down industrial production in order to decrease additional industrial pollution during the fire-generated smog. Daily production losses were ca US$ 8 million.

- Australia's Ash Wednesday Fires of 1983:
  - Human death toll: 75
  - Burned homes: 2539
  - Burned domestic livestock: nearly 300,000

- Extended forest and savannah fire in Côte d'Ivoire 1982-83:
  - Human death toll: > 100
  - Burned land area: 12 million hectares
  - Burned coffee plantations: 40,000 hectares
  - Burned cocoa plantations: 60,000 hectares

- Forest fires in the Northeast of the People's Republic of China during the 1987 drought:
  - Human death toll: 221
  - Burned forest: 1.3 million hectares
  - Homeless population: 50,000
  - Total human death toll 1950-90 (all China): 4,123

- Fire episode in the Soviet Union during the 1987 drought:
  - Burned forest: 14.5 million hectares

- Mongolia steppe and forest fires 1996-97:
  - Burned area 1996: 10.7 million hectares
  - Human death toll: 25
  - Burned domestic animals: 7000
  - Burned stables/houses: 576/210
  - Damage assessment: US$ 2 billion

  - Burned area 1997: 12.4 million hectares

- Yellowstone National Park (USA) 1988:
  - Suppression costs: US$ 160 million
  - Loss in tourist revenues between 1988 and 1990: US$ 60 million

Impact of fire-generated smoke on human health

Smoke pollution generated by wildland fires occasionally creates situations during which public health and local economies are affected. Fatalities in the general public caused by excessive carbon monoxide concentrations alone or in combination with other pollutants have been reported from various fire events, e.g. the above forest fires in China in 1987. Epidemiological studies indicate associations between the levels of air pollutants (especially particle air pollution) produced from wildland fires and a range of adverse health impacts, including increased mortality.

The use of fire in forest conversion and other forms of land clearing, and wildfires spreading from these activities, are very common in tropical countries. In the 1980s and 1990s most serious pollution problems were noted in the Amazon Basin and in the South East Asian region. The most recent large smog episodes in the South East Asian region were in 1991, 1994 and 1997 when land-use fires and uncontrolled wildfires in Indonesia and neighbour countries created a regional smog layer which lasted for several weeks. In 1994, the smoke plumes of fires burning in Sumatra (Indonesia) reduced the average daily minimum horizontal visibility over Singapore to less than 2 km; by the end of September 1994 the visibility in Singapore dropped to as low as 500 metres. At the same time the visibility in Malaysia dropped to 1 km in some parts of the country. In 1997, smoke from the fires resulted in elevated levels of particle air pollution for a period of several months in many areas (beginning in late July 1997), with a severe episode occurring during most of the month of September. During this period particle levels in some areas were up to 15 time higher than normal levels. For example, a 24-hour average PM_{10} (mass of particles with aerodynamic diameters smaller than 10 micrometre) concentration of 930 $\mu g/m^3$ was recorded in the city of Kuching (Sarawak Province, Malaysia); the government was close to evacuating the 300,000 inhabitants of the city (Brauer and Hisham-Hashim, 1998).

In the same regions, the smoke from fires disrupted local and international air traffic. In 1982-83, 1991, 1994 and 1997-98 the smog episodes in South East Asia resulted in closing of airports and marine traffic, e.g. in the Strait of Malacca and along the coast and on rivers of Borneo. Several smoke-related marine and aircraft accidents occurred during late 1997. The loss of an aircraft and 234 human lives in September 1997 in Sumatra was partially attributed to air traffic control problems during the smog episode.

Wildfires burning in radioactively contaminated vegetation lead to uncontrollable redistribution of radionuclides, e.g. the long-living radionuclides caesium (^{137}Cs), strontium (^{90}Sr) and plutonium (^{239}Pu). In the most contaminated regions of the Ukraine, Belarus and the Russian Federation (the Kiev, Zhitomir, Rovmo, Gomel, Mogilev and Bryansk Regions), the prevailing forests are young and middle-aged pines and pine-hardwood stands which have high fire danger classes. In 1992 severe wildfires burned in the Gomel Region (Belarus) and spread into the 30-km radius zone of the Chernobyl Power Plant. Research reveals that in 1990 most of the ^{137}Cs radionuclides were concentrated in the forest litter and upper mineral layer of the soil. In the fires of 1992 the radionuclides were lifted into the atmosphere. Within the 30-km zone the level of radioactive caesium in aerosols increased 10 times. For more details on resuspension of radioactive matter from forest fires see the comprehensive analysis of Dusha-Gudym (1996).

Smoke generated by domestic burning of biofuels

Domestic biofuel burning must be mentioned here because its contribution to ambient air pollution often mixes with wildfire and land-use fire emissions, especially in developing countries. Biofuels, in the form of wood, charcoal and agricultural waste is a major source of energy in the developing world. For instance, in Western Africa, wood fuel represents 60 to 90% of the energy consumed. The developing countries in which the biomass share is weaker (around 60%) are either oil-producing countries, countries with a high hydroelectric potential, or countries which have a sound economic stability. Charcoal production for domestic and industrial use has also become an attractive alternative to the direct use of wood as fuel. Unlike the occurrence of free-burning vegetation fires, which is usually restricted to several months during the dry season, domestic biofuel combustion takes place during the whole year. A tentative global analysis shows that the source strength of carbon released as CO_2 and CO by domestic biomass burning is in the order of 1.6 billion metric tons (Ludwig et al., 1999).

2.1.2 HAZARD ASSESSMENT AS THE BASIS OF RISK ANALYSIS

Early warning systems for fire and smoke management for local, regional, and global application require information at various levels. Information on current weather and vegetation dryness provides the starting point of any predictive assessment. From this information the risk of wildfire starts and the prediction of current fire behaviour and impacts can be derived. Short- and long-range fire weather forecasts allow the assessment of fire risk and severity within the forecasting period. Advanced space-borne remote sensing technologies allow fire weather forecasts and vegetation dryness assessment of large areas (local to global), with an economy and accuracy that cannot be met by ground-based collection and dissemination of information. Remote sensing also provides capabilities for detecting new wildfire starts, for monitoring ongoing active wildfires and, in conjunction with fire-weather forecasts, serves as an early warning tool for escalating, extreme wildfire events (UNEP, 1999).

Fire danger rating (fire risk assessment)

Authorities responsible for fire fighting have devised fire danger rating systems to provide early warning of conditions conducive to the onset and development of extreme wildfire events. The factors that predispose a particular location to extreme wildfire threat change over times measured in decades, years, months, days and hours. The concept of fire danger involves both tangible and intangible factors, physical processes and hazard events. By definition:

> *"Fire danger" is a general term used to express an assessment of both constant and variable factors affecting the inception, spread, intensity and difficulty of controlling fires and the impact they cause.*

Fire danger rating systems produce qualitative and/or numerical indices of fire potential that can be used as guides in a variety of fire management activities, including early warning of fire threat. Different systems of widely varying complexity have been developed throughout the world, which reflect both the severity of the fire risk and the needs of fire management.

While a single fire danger index may be useful for providing early warning of wildfire activity over broad areas, it is impossible to communicate a complete picture of the daily fire danger with a single index. Therefore, it is necessary to break fire danger ratings into major components to appreciate where single factors fall in the overall picture. These fall into three broad categories of early warnings of fire precursors:

- changes in fuel load
- changes in fuel availability
- changes in weather variables that influence fire spread and intensity

Details on these early warning systems are given in the background papers to these guidelines.

Use of satellite data to help assess fire potential

The amount of living vegetation, and its moisture content, has a strong effect on the propagation and severity of wildland fires. The direct observation of vegetation greenness is therefore essential for any early warning system. Current assessment of living vegetation moisture relies on various methods of manual sampling. While these measurements are quite accurate, they are difficult to obtain over broad areas, so they fail to portray changes in the pattern of vegetation greenness and moisture across the landscape.

The current polar orbiting meteorological satellites provide the potential for delivering greenness information and other parameters needed for fire management and fire impact assessment, with daily global coverage and coarse spatial resolution. This is achieved using wide angle scanning radiometers with large instantaneous fields of view, e.g. the AVHRR instrument of the NOAA, which measures reflected and emitted radiation in multiple channels including visible, near-infrared, middle-infrared, and thermal. Because of its availability, spatial resolution, spectral characteristics, and low cost, the AVHRR has become the most widely used satellite data set for regional fire detection and monitoring. Currently, AVHRR data are used for vegetation analyses and in the detection and characterisation of active flaming fires, smoke plumes, and burn scars.

Since 1989 the utility of using the Normalised Difference Vegetation Index (NDVI) to monitor seasonal changes in the quantity and moisture of living vegetation has been investigated. Daily AVHRR data are combined into weekly images to remove most of the cloud and other deleterious effects, and an NDVI image of the continental US is computed by the Earth Resources Observation Systems (EROS) Data Center (EDC) of the US Geological Survey (USGS, 1999a). These weekly images are further processed into images that relate to fire potential and that are more easily interpreted by fire managers. All these images can be addressed via the Internet.

2.1.3 FIRE WEATHER FORECASTS

Improved fire weather forecasts are needed at a variety of time and space scales. At large space and time scales, accurate fire weather forecasts are potentially useful for the long range planning of scarce resource allocations. At smaller time and space scales accurate fire weather forecasts have potential use in alerting, staging and planning the deployment of fire suppression crews and equipment. At the smallest time and space scales, accurate fire weather forecasts can be helpful in fighting fires as well as determining optimal periods for setting prescribed silvicultural and agricultural fires.

Global to regional forecasts of the fire weather index and precipitation are currently displayed on the worldwide web site of the Experimental Climate Prediction Center (ECPC) of the Scripps Institute of Oceanography (ECPC, 1999). Experimental global to regional forecasts for other regions are also under development. Additional land surface variables such as snow, soil and vegetation moisture are now being extracted and may soon be provided as part of the forecasts; these additional variables are needed to transform fire weather indices into fire danger indices, which include vegetation stresses.

2.2 SOURCE CHARACTERIZATION: EMISSION AND POST-EMISSION PROCESSES

2.2.1 INTRODUCTION

Biomass burning is a major contributor of toxic gaseous and particle air pollutants and greenhouse gases throughout the world, in many instances resulting in human exposure to high levels of various air pollutants. But unlike some anthropogenic sources, it is poorly quantified. The nature of biomass burning is such that the combustion is not complete, and as a result a large number of pollutants are emitted. For example, particulate matter (PM), oxides of nitrogen (NO_x), sulphur dioxide (SO_2) and carbon monoxide (CO) are among the air pollutants (or their precursors) that are often of most concern for general population exposures. The emission of e.g. sulphur- and nitrogen-based compounds depends both on the efficiency of the combustion process and the chemical composition of the vegetation burned.

After the emission, during transport, the combustion emissions undergo physico-chemical changes. While exposure to most airborne pollutants can potentially have detrimental health effects, recent scientific evidence indicates that airborne particles, especially those which are very small (aerodynamic diameters below 2.5 μm), could have the most significant health effects. These particles have very high probability of deposition in deeper parts of the human respiratory tract where they may lead to a range of health effects by virtue of their physical, chemical, toxicological or carcinogenic nature. The adverse health effects of small particles and their relative abundance in emissions are why particles receive more attention than other pollutants when considering exposure to smoke plumes from biomass burning. Reasonable estimates of exposure to other compounds can be obtained from ratios of toxic air compounds to CO, CH_4, and/or $PM_{2.5}$ (mass of particles with diameters smaller than 2.5 micrometres), based on the characterization of one or two compounds. Of course, this assumes that the emissions are from biomass burning or that the contribution of biomass burning can be apportioned. In general, comprehensive standardized approaches for dealing with the potential public health risks of biomass fires emissions should include:

(a) Characterization of the magnitude and composition of the emissions and their transformations during transport;

(b) Quantification of resulting concentrations of toxic air pollutants in ambient air in populated areas;

(c) Evaluation of likely exposure scenarios for affected populations (both indoors and outdoors);

(d) Assessment of consequent health risks posed by such human exposures.

2.2.2 FACTORS AFFECTING INCOMPLETE COMBUSTION

Combustion efficiency is defined as the ratio of carbon released as CO_2. For convenience, the modified combustion efficiency is defined as the ratio of the carbon released as CO_2 divided by the sum of the CO_2 and CO released. Alternatively, dividing the amount of CO released by the CO2 released gives an approximate measure of combustion efficiency. Ratios of CO to CO_2 range from approximately 0.04 for flaming combustion to more than 0.25 for smouldering combustion. Smouldering combustion is limited to situations where the fuel is consumed by non-flaming processes and is generally a very low-intensity combustion process. It produces high emissions of particulate matter, CO, and other compounds of incomplete combustion. Fuel properties can markedly affect both the amount of smouldering combustion and the overall mixture of emissions. With savanna ecosystems, for example, 90% of the vegetation may be consumed through flaming combustion. This would be quite different from a fire burning in a vegetation types, such as peat, rotten logs, rotten wood residues (“deep duff”) etc., where 90% would be consumed through smouldering combustion. It should be noted that the combustion of peat can consume over 17 metric tons/ha-cm, which translates into as much as 1.5 metric tons of CO/ha-cm of peat depth consumed by fire (depending on the density of the biomass).

2.2.3 POLLUTANTS GENERATED BY COMBUSTION

In the study of smoke and its effect on the health of wildland firefighters, Ward and his collaborators discussed several combustion emissions and classes of combustion emissions (Ward et al., 1989). These substances are categorized as follows:

1. Particulate matter (PM)
2. Polynuclear aromatic hydrocarbons (PAH)
3. Carbon monoxide (CO)
4. Aldehydes
5. Organic acids
6. Semi-volatile and volatile organic compounds (VOC)
7. Nitrogen- and sulphur-based compounds
8. Free radicals

9. Ozone and photochemical oxidants
10. Inorganic fraction of particles

Particulate matter from wildland fires is highly visible, affects ambient air quality, and potentially has a very significant effect on human health. Forest fires abundantly produce particles with source strengths exceeding 0.6 metric tons per second on some large fires (Wade and Ward, 1973). In terms of number, the majority of particles emitted from biomass burning are ultra-fine, with only a small fraction in the larger size range (Fig. 2.2.3-1a, 1b; Morawska et al. (1998); Morawska and Thomas (1999)). This is similar to emissions from any other combustion source. Ultra-fine particles are defined as those having a diameter smaller than 0.1 micrometre. Fine particles are smaller than 2.5 micrometres, and coarse particles are larger than 2.5 micrometres. Ultra-fine particles rapidly agglomerate to form fine particles.

The mass of particles from biomass burning can be separated into two modes: a fine-particle mode with a median diameter of 0.3 micrometres, generally considered to be produced during the combustion of organic material, and a coarse particle mode with a median diameter larger than 10 micrometres. Research, both from ground-based (Ward and Hardy, 1989) and airborne sampling, shows the bimodal distribution with a small fraction of the total mass (less than 10%) between 2 and 10 micrometres (Radke et al., 1990). Indeed, available data indicate that most particulate matter produced by combustion of either fossil or biomass fuels is found in particles less than 2.5 micrometres in aerodynamic diameter (USEPA, 1998a), with fine particles accounting for 90-100% of the particulate matter. Smouldering combustion releases several times more fine particles than flaming combustion.

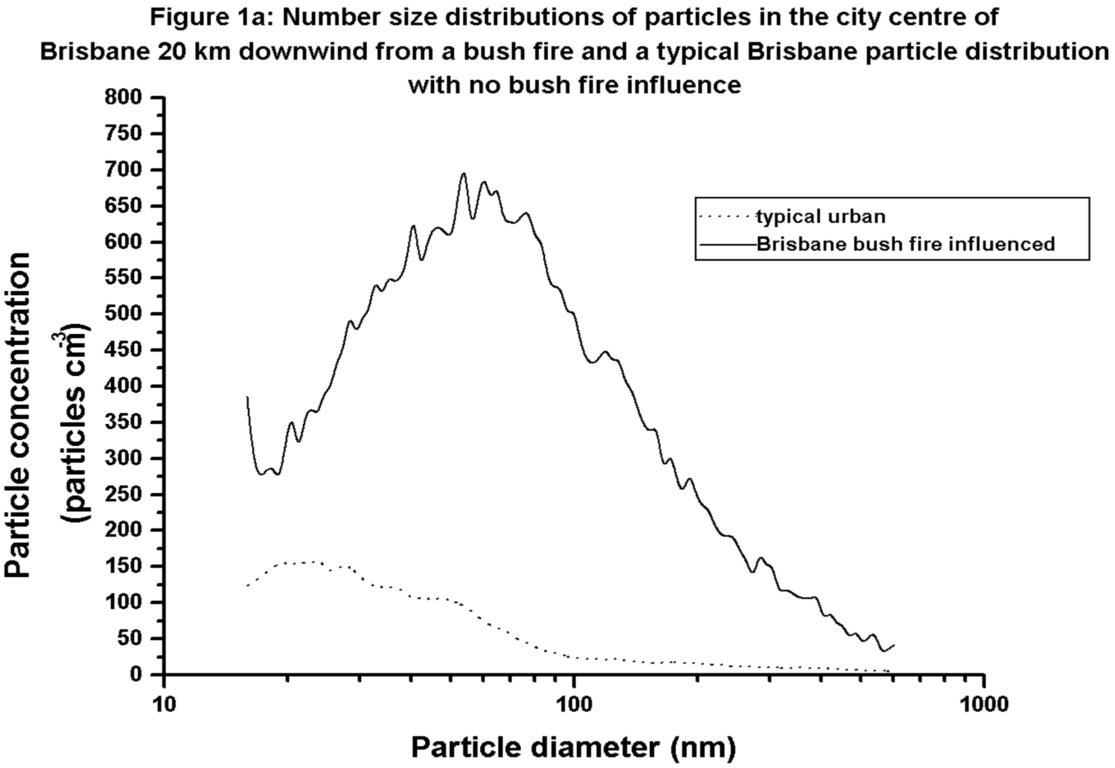
Figure 1a: Number size distributions of particles in the city centre of Brisbane 20 km downwind from a bush fire and a typical Brisbane particle distribution with no bush fire influence

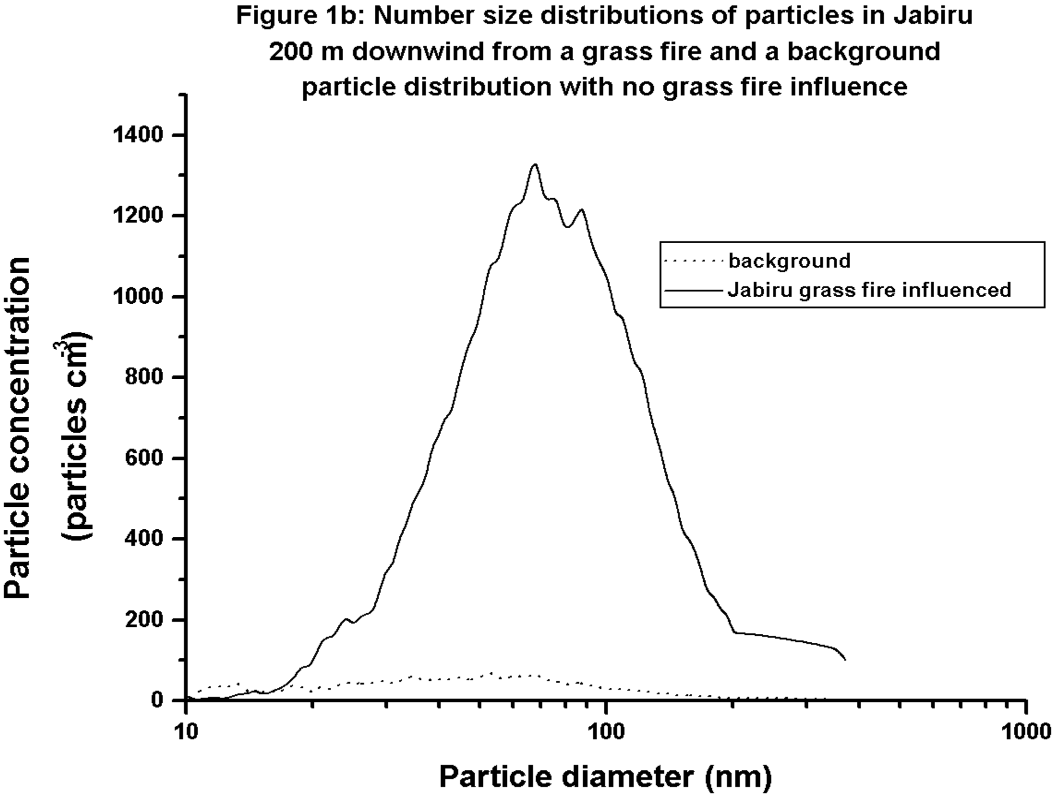
Figure 1b: Number size distributions of particles in Jabiru 200 m downwind from a grass fire and a background particle distribution with no grass fire influence

Figure 2.2.3-1a, 1b (Morawska and Thomas (1999))

Fine particles consist of 60 to 70% organic carbon [Ward and Hardy, 1989). Roughly, another 2 to 15% is graphitic carbon and the remainder is inorganic ash material (Ward and Core, 1984). Many known carcinogenic compounds are contained with the organic carbon fraction and particles are also known to carry adsorbed trace elements, condensed toxic elements and possibly free radicals.

For public exposure, the fine particles are of primary concern. Recent research (summarized in USEPA, 1998a; Wilson and Spengler, 1996) has found evidence for small, but significant, increases in mortality due to exposure to low levels of PM_{10}. A better correlation between health and airborne particulate matter has been found for the $PM_{2.5}$ fraction than for the PM_{10} (Dockery et al., 1993). Since most of the number and mass of particulate matter generated from biomass burning is in the fine particle size range (below 2.5 micrometres), a better characterization of health risk requires a measurement of the $PM_{2.5}$ fraction.

Polynuclear Aromatic Hydrocarbons (PAH) is one class of compounds contained in the organic fraction of the fine particle matter. Some of the PAH compounds associated with the particles are carcinogenic. A compilation of the health effects of selected non-heterocyclic PAH has recently been published by WHO (1998a). PAHs considered included acenaphthene, acenaphthylene, anthracene, benzo[a]pyrene, benz[a]anthracene, dibenz[a,h]anthracene, fluoranthene, naphthalene, phenantrene, and pyrene. The most studied PAH is benzo[a]pyrene B[a]P which is a physiologically active substance that can contribute to the development of cancer in cells of humans. Despite the known presence of carcinogenic substances in particles produced from biomass combustion, limited data do not indicate an increased cancer risk even at very high levels of exposure. This evidence includes studies of long-term exposure to high levels of biomass smoke from domestic cooking in developing countries. Further, while biomass smoke is clearly mutagenic, it is much less so than motor vehicle exhaust, on a comparable mass basis (Brauer, 1998). PAH compounds observed in smoke from prescribed fires in logging slash (wood residues) and laboratory fires of pine needles include the following species (Ward et al., 1989; McMahon and Tsoukalas, 1978; DeAngelis et al., 1980): Anthracene, Anthanthrene/dibenzopyrene, Benz[a]anthracene, 1,2-Benzanthracene, Benzo(a)fluoranthene, Benzo(a)pyrene, Benzo(e)pyrene, Benzo(b/j/k)oranthenes, Benzofluoranthene, Benzo(ghi)fluoranthene, Benzo[ghi]perylene, Chrysene, Methylanthracenes, Dibenzanthracenes /dibenzphenanthrenes, Fluoranthene, Indenopyrene, Phenanthrene, Perylene, Pyrene.

For comparative purposes, a set of ambient air samples were collected in Sumatra, Indonesia over the period November 4th-8th, 1997 (Pinto et al., 1998a). The sparse data set suggests the PAH concentrations could be higher than for logging slash and pine needle fire smoke by a factor of 2 to 5. Not all of the compounds listed above are of equal carcinogenicity. More data have been developed for B[a]P than other PAH compounds for smoke from wildland fires. Ward et al. (1989) found for B[a]P that emission factors increased proportionally with the density of live vegetation covering the prescribed fire units. This has not been verified for other ecosystems with live vegetation involved in flaming combustion.

PAH compounds are synthesized from carbon fragments into large molecular structures in low-oxygen environments, such as occurs inside the flame envelope in the fuel-rich region of the flame structure. If the temperature is not adequate to decompose compounds upon exiting from the flame zone, they are released into the atmosphere and condense or are adsorbed onto the surface of particles. Many different combustion systems are known to produce PAH compounds, and the burning of forest fuels is documented as one of these sources. Little is known about combustion conditions in wildfires, but recent experiments suggest that emissions do not differ too much from those of prescribed fires, when burning conditions are similar. Evidence suggests that for low-intensity backing fires, the ratio of benzo[a]pyrene to particulate matter is higher by almost 2 orders of magnitude over that for heading fires (McMahon and Tsoukalas, 1978). For wood stoves, a relationship was established between burning rate and PAH emission. Specifically, as the burning rate increased, total organic emissions decreased, but the proportion of PAH compounds increased. De Angelis et al. (1980) found the PAH emission rate to be highest over a temperature range of 500 to 800 ^{o}C. This would be consistent with the low- intensity backing fire results of McMahon and Tsoukalas (1978).

Carbon monoxide is a colorless and odorless toxic gas produced through the incomplete combustion of biomass fuels and is less abundant than CO_2 and water vapor. Carboxyhemoglobin is created in the blood of humans in response to CO exposure, which replaces the capacity of the red blood cells to transport oxygen. Generally, a level of 5% carboxyhemoglobin results from 3 to 4 hours exposure to CO concentrations of 35 ppm and may result in people showing signs of disorientation or fatigue.

CO is produced more abundantly from smouldering combustion of forest fuels. Immediately following the cessation of flaming combustion, maximum levels of CO are produced. This phenomena coincides with suppression activities, especially where direct attack methods are being used. As the flames subside, CO is released at the highest rate and, typically, continues at a high rate during the first few minutes of the die down period. For fires burning under high drought conditions, the smouldering combustion can be self-sustaining and consume deep into the duff, and in some cases soil, where the organic component of the soil makes up more than 30% of the total. Tremendous amounts of smoke can be produced under severe conditions, sometimes sustained for days and weeks.

Aldehydes. A few aldehydes are extremely irritating to the mucous membranes of the human body. Some, such as formaldehyde, are potentially carcinogenic and in combination with other irritants may cause an increased risk of carcinogenesis. Formaldehyde is one of the most abundantly produced compounds of this class and is released proportionally to many of the other compounds of incomplete combustion. In the human body, formaldehyde is transformed rapidly to formic acid, which is removed very slowly. The ability of scavenger cells in the lungs to engulf foreign bacteria is decreased through exposure to aldehyde compounds, which may accentuate infections of the respiratory system.

Acrolein, another aldehyde, is also emitted during incomplete combustion of forest fuels. In smoke from cigarettes, acrolein is about 10 times more plentiful than formaldehyde. According to Dost (1986) acrolein concentrations could be as high as 0.23 to 23 mg/m^3 near fires and likely increase the irritant character of smoke near fire lines. The threshold levels of acrolein that cause irritation and health effects are 0.07 mg/m^3 for odour perception, 0.13 mg/m^3 for eye irritation, 0.3 mg/m^3 for nasal irritation and eye blinking, and 0.7 mg/m^3 for decreased respiratory rate (WHO, 1991). In animal studies, both respiratory tract function and histopathological effects have been observed at 0.5-0.8 mg/m^3 (continuous exposure, WHO, 1991). Aldehydes have been difficult to quantify for forest fires and there are still many issues to be worked out. Some recent research by Reinhardt (1994) suggests that acrolein is produced proportionally to formaldehyde. On the other hand Yokelson et al. (1996), using a straightforward analytical technique, were not able to identify acrolein in as high concentrations as those reported by Reinhardt (1994) and it was much less abundance than formaldehyde.

Organic acids are emitted in the combustion of biomass fuels. Yokelson et al. (1997) and McKenzie et al. (1995) have recently made significant progress in characterizing some of the emissions of organic acids, including acetic and formic acid, finding molar ratios to CO of 7.4 ± 6.2 and 1.5 ± 1.5, respectively. From the molar ratios of different toxic air compounds to CO, McKenzie et al. (1995) reported possible exposure levels well below the allowable time weighted average values (TWA) based on a peak exposure of firefighters of 54 ppm (Reinhardt, 1994). It should be noted that the synergistic effects of these and other compounds have not been determined.

Semi-volatile and volatile organic compounds. Many such compounds in smoke have significant vapor pressures at ambient temperatures. Some compounds are partitioned between the gaseous and liquid or solid phase at ambient temperature; e.g., benzene, naphthalene, toluene. Fires are known to produce a variety of these compounds, but little characterization work has been done. Phenol compounds are important because they are very strong irritants abundantly produced from the partial oxidation of cellulose fuels. Other PAH compounds of low-molecular weight are contained within the semi-volatile class of compounds. Because of the volatility, and in some cases reactivity, of these compounds special sampling protocols are required, including charcoal adsorption, porous polymer adsorption, and whole-air sampling. These compounds are difficult to sample, and surrogate methods are needed for correlating exposures of the more volatile components with the semi-volatile components. Methane and carbon monoxide gases are often produced proportionally to other compounds of incomplete combustion and may serve as indicators of their abundance.

Nitrogen- and sulphur-based compounds are produced from the combustion of vegetation containing nitrogen and sulphur, respectively. Smouldering combustion produces reduced nitrogen compounds such as NH_3 whereas flaming combustion produces oxides of nitrogen. Although it is possible for flames to reach temperatures where molecular nitrogen in the atmosphere may dissociate, this is very uncommon and is believed to occur in only the very highest intensity wildfires. Research by Yokelson et al (1996) and Lobert et al (1991) have demonstrated the relationship between combustion efficiency and the release of ammonia (NH_3) and oxidized combustion compounds. They found that as CO release increases relative to CO_2, the emission of NH_3 increases relative to NO_x. The release of hydrogen disulphide (H_2S_2) relative to SO_2 is believed to follow a similar relationship. It should be emphasized that both the nitrogen and sulfur based compounds are produced proportionally to the content of these elements in the burning vegetation and as a function of the combustion efficiency for the fire.

Free radicals are abundantly produced through the combustion of forest fuels. The concern lies with how long these materials persist in the atmosphere and their reactivity when in contact with human tissues. Most free-radical groups undergo condensation within the few seconds it takes for the mixture of gases to exit the flame, which should reduce the overall toxicity of the smoke. However, some free radicals persist up to 20 minutes following formation and may be of concern to people exposed to fresh aerosols in the vicinity of fires. How much of the organic material remains in a reactive, free-radical state is unknown.

Ozone concentrations that are high enough to be of concern would not be expected close to fires. Ozone is formed photo-chemically near the top of smoke plumes under high sunlight conditions. Generally, ozone is formed in situations where smoke is trapped in valleys or under temperature inversions of the atmosphere, or both. Fire crews working at high elevation locations may encounter elevated levels of ozone. Any effort to characterize the exposure of people to smoke must account for potential exposure to ozone when personnel are working at elevations close to the top of the atmospheric mixing layer.

2.2.4 TRANSFORMATION OF COMBUSTION COMPOUNDS DURING TRANSPORT

After formation, the highly dynamic mixture of combustion compounds is transported from the emission site. During transport the compounds change their chemical composition, physical characteristics and concentration in the air. The residence time of the combustion compounds in the air depends on the nature of the processes they are involved in and varies from seconds or minutes, to days or weeks.

Aerosols are formed either from primary emissions (generally solids) or secondary emissions (generally liquids). Larger particles, having an aerodynamic diameter of a micrometre or greater, are produced mainly by primary processes, including mechanical, and are removed from the atmosphere mainly through gravitational settling. For example, at a distance of 20 km from an extensive fire, while sub-micrometre particle concentration is significantly increased, there is no increase in particles over one micrometre, indicating the particles have been removed from the air plume while travelling over this distance (Morawska et al, 1998). The smaller particles are transformed mainly by coagulation and condensation and are removed from the air by coagulation into larger particles or through in-cloud scavenging during precipitation. The size distribution of particles changes during the transport process: particles from the nucleation mode (size range of nanometres to tens of nanometres) move to the accumulation mode (size range in general below one micrometre), while coarser particles are removed from the air by the deposition process. The changes are faster immediately after the particles are generated and slow as the particle concentration decreases through dilution or transformation. The residence times of particles in air vary significantly, and for the very large particles could be of the order of minutes, while particles smaller than one micrometre can last in the air for weeks, depending on meteorological conditions. In the troposphere these particles can even last up to years (Subcommittee on Airborne Particles, 1979). The size distribution of the particles is important for health risk assessment, as smaller particles have a larger probability of deposition in deeper parts of the respiratory track.

The lifetimes of chemical compounds emitted into the atmosphere by burning vegetation vary widely. For many species, the primary controlling factor for post-formation changes is transformation/destruction by the OH (hydroxyl) radical. Non-methane hydrocarbons such as C_2-C_4 alkenes are typically lost by reaction with OH radicals over a few hours, while loss of C_2-C_4 alkanes occurs over a few days to a few weeks. Carbon monoxide has an atmospheric lifetime of about 2-3 months, while that of CH_4 is about ten years. Nitrogen oxides are converted to HNO_3 typically over several hours. A number of compounds (e.g. formaldehyde, HCHO) are produced by photochemical oxidation of the above species (which is of potential interest from a human health standpoint). The atmospheric lifetime of HCHO is about an hour. The residence times of gases emitted in the smoke plumes of forest fires can be estimated from other studies. The transformation/destruction rates are generally measured in laboratory experiments and some examples of these are tabulated in DeMore et al. (1997). Table 2.2.4-1 gives typical residence times in the lower troposphere for OH number densities of $10^6 cm^{-3}$, which should be appropriate for tropical vegetation fires. The residence times of hydrocarbons can vary from very short, i.e., a few days, to very long, e.g. 7.3 years for methane.

Table 2.2.4-1

Typical residence times for molecular species emitted during forest fires.

Species	Residence time (years)	Reference
CH_4	7.3	Miller et al. (1998)
C_2H_2	0.04	Ehhalt et al. (1998)
C_2H_6	0.19	Colman et al. (1998)
CH_3Cl	1.26	Colman et al. (1998)
CO	0.25	Colman et al. (1998)
NO	0.035	Koike et al. (1996)
O_3	0.044	Davis et al. (1996)
Aerosols	0.02	Baker et al. (1979)

Ozone is produced downwind of vegetation fires over a period of several hours through the action of photolysis on hydrocarbons and NO_x ($NO + NO_2$), provided sufficient ultraviolet radiation is available to initiate oxidation reactions. In dense smoke plumes, ozone would be produced more rapidly in the upper layers of the plume. The formation of tropospheric ozone from vegetation fires in the tropics has been explored in depth during the first intercontinental set of fire experiments in the frame of the Southern Tropical Atlantic Regional Experiment (STARE) components. These components are the Transport of Atmospheric Chemistry Experiment-Africa (TRACE-A) and the Southern Africa Fire-Atmosphere Research Initiative (SAFARI). The latter is a fire research component of the Biomass Burning Experiment (BIBEX) of the International Geosphere-Biosphere Programme (IGBP), International Global Atmospheric Chemistry (IGAC) core project (Helas et al. 1995; Lindesay et al., 1996; Singh et al., 1996; van Wilgen et al. 1997; GFMC, 1999b).

Plumes from vegetation fires can travel at 500–1000 kilometers or more in several days (Browell et al., 1996). For example, at wind speeds of $4 ms^{-1}$, a plume would travel 480 km in 5 days. Plumes can, of course, travel much longer than 5 days. During another NASA mission in the South Pacific in late 1996, plumes were found that were about 20 days old (Blake et al., 1999). Thus, some of the molecular species would be relatively unchanged while others would have significantly reduced concentrations.

2.2.5 EMISSION RATIOS TO BE USED FOR CRITERIA POLLUTANTS

Ratios of toxic air pollutants to CO, CH_4, and $PM_{2.5}$

In performing a risk assessment and establishing the relative importance of different compounds for human health, a method is needed to estimate the exposure levels based on the measurement of CO and/or PM. Many of the compounds discussed are very difficult to measure, which makes sampling of the breathing space and/or ambient air nearly impossible for most of the toxic compounds. However, correlating the concentration of toxic air compounds with those of CO, CH_4, and $PM_{2.5}$ has proved to be an effective way of estimating the release of a number of compounds (Ward et al, 1993; McKenzie et al, 1995; Yokelson et al., 1997). Some ratios are presented in Table 2.2.5-1.

Table 2.2.5-1: Molar ratios of toxic air pollutants to CO (x 10^{-3}), averaged for a variety of fuel types.

Compound	Ratio	Compound	Ratio	Compound	Ratio
Methane	104.8	Ethane	6.7	1,3-Butadiene	1.10
Ammonia	26.0	HCN	4.0	m-/p-Xylene	0.43
Formaldehyde	17.3	Benzene	2.13	Phenol	0.32
Formic acid	15.2	Toluene	1.79	o-Xylene	0.24

If this method is to be used, it is important to make “safe-side” estimates, or to use very specific information for the phase of combustion producing the smoke of concern. For example, ratios of B[a]P to CO and/or to PM for different fuel types show a significant difference between flaming (F), primary smouldering (S1) and secondary smouldering (S2) combustion (see Table 2.2.5-2). There is almost an order of magnitude difference in emission ratios of B[a]P to CO between flaming and smouldering. An average weighted emission ratio can be calculated from the percentage of fuel consumed by the respective phase of combustion producing the emissions. This can be done by assuming, for example, that the emissions along the fire line consist of 10 % from vegetation consumed during the flaming phase, 70% for the first smouldering phase and 20% for the final smouldering phase. These results are illustrated in Table 2.2.5-2.

Table 2.2.5-2 Application of data for prescribed fires in the Pacific Northwest. The ratios can be multiplied by the concentration of CO to calculate either B[a]P or PM exposure. If only PM exposure is available, CO can be calculated and B[a]P estimated, along with other toxic air pollutants found in Table 2.2.5-1.

Phase of combustion	**CO [ppm]**	**PM [µg/m^3]**	**B[a]P [µg/m^3]**	**B[a]P/CO [µg/m^3/ppm]**	**B[a]P/PM [10^{-6}]**	**PM/CO [µg/m^3/ppm]**
F	140	15740	0.1284	0.0009	8.2	112.4
S1	113	8391	0.1608	0.0038	42.8	74.3
S2	26	1214	0.1024	0.0067	126.4	46.7
Weighted	98	7690	0.1459	0.0040	56.1	78.2

On the other hand, emissions released through flaming combustion are generally accompanied by the release of significant heat, which transports the emissions to higher altitudes through convection forces acting on the smoke plume. Most of the emissions near the surface may be produced through smouldering combustion. It is recommended that emission ratios for smouldering combustion are used for assessing exposure, except for those conditions where 75 to 80% or more of the fuel is consumed through flaming combustion.

2.2.6 EXPOSURE LEVELS IN AIR POLLUTION EVENTS

Exposure regimes differ quite substantially for different vegetation fire events. Examples of extensive and wide-spread fire events are presented in the background papers.

2.2.7 SUMMARY

Biomass burning is a major contributor of toxic air pollutants, particulate matter, and greenhouse gases throughout the world. In many instances this results in human exposure to high levels of various air pollutants, but unlike some anthropogenic sources, it is poorly quantified. While exposure to most of the airborne pollutants can have potentially detrimental health effects, recent evidence indicates that very small airborne particles could have the most significant health effects. Since most of the number and mass of particulate matter from biomass burning is in the fine particle size range, a better characterization of health risks requires measurement of the $PM_{2.5}$ fraction.

Transformations that occur during the downwind transport of smoke are poorly understood, but are known to have a significant effect on the composition of the smoke at the exposure locations. Using the ratios of air toxic compounds to CO, CH_4, and/or $PM_{2.5}$, reasonable exposure estimates for a number of other compounds can be obtained, based on the characterization of only one or two compounds.

2.3 GROUND-BASED MONITORING

2.3.1 OBJECTIVES

Ground-based air quality monitoring should aim to attain the following objectives:

- Provision of information for
    - public health warning
    - decision making and initiation of protective measures

- Provision of data for
    - model inputs/model verification and development
    - human health studies to evaluate effects of smoke haze.

2.3.2 BACKGROUND

Ground-based air quality monitoring of forest fires should emphasize PM as the major pollutant in the smoke or haze. Monitoring is important both for forecasting haze events and for emergency response. In particular, $PM_{2.5}$ should be measured, since the fine fraction predominates in the smoke and haze and is thought to be responsible for the observed health effects. However, if the $PM_{2.5}$ cannot be measured, either PM_{10} or total suspended particles (TSP) should be measured. In the absence of PM measurement, visibility can be used as an indicator of ambient particle concentration.

Measurements carried out in Singapore and Malaysia during the smoke and haze event of 1997 indicated that PM_{10} levels were by far the most elevated of all pollutants (O_3, NO_x, SO_2, CO, PM_{10}), compared to normal background values. However, during haze episodes, measurements of additional pollutants such as O_3, NO_x, SO_2, CO, aldehydes, and PAHs allow a more comprehensive assessment of the health risks resulting from exposure to haze. This procedure is in line with a previous publication of WHO on health risk assessment in smog episodes (WHO, 1992b).

2.3.3 NETWORK DESIGN CONSIDERATIONS

A network for haze and smoke monitoring would start with local meteorological and air pollution monitoring stations. When these stations are assembled into a network, the status of the regional smoke and haze can be determined. When there is an existing meteorological and/or air pollution-monitoring network, sites that best meet certain smoke and haze conditions (described below) should be identified and could be designated as special haze monitoring sites. If necessary, these monitoring stations should be equipped with additional monitoring instruments. The minimum measurement set should consist of measurements of particulate matter, meteorological parameters and solar radiation on a continuous basis. If the plume is above the mixing layer and pollution levels cannot be detected at ground level, a solar radiometer could be used to detect the plume as it passes overhead by the reduction in solar radiation.

To examine the effects of air pollutants from distant sources on a local population, one or more monitors should be located at sites expected to be impacted by the emissions before they reach the more densely populated areas. These experimental sites could be identified on the basis of most likely transport routes from fire prone areas. Thus, the contributions from local urban air pollution sources can, in principle, be separated from those of distant sources. Data from such sites can also be used for health studies of the non-urban population. In addition, monitoring at sites unaffected both by the long-range transport of pollutants and by high levels of local pollution could serve as control sites.

Additional factors that should be considered in the design of monitoring networks include the objectives of the monitoring program, spatial and temporal coverage, and performance specifications (such as precision and accuracy of the monitoring devices). Other objectives include the temporal response, the siting of individual monitors and detailed site information, the management of data, and the development of a quality assurance/quality control plan.

The following items should be addressed before going into a detailed network design:

- Review of existing air quality/meteorological monitoring activities in fire/haze prone areas.
- Identification of appropriate sites for smoke and haze monitoring and their incorporation into a special monitoring network.
- Enhancement of the existent monitoring networks to measure smoke and haze-related quantities.
- Identification of agencies responsible for air pollution measurement/collection.

A quality assurance/quality control plan is essential for ensuring maximum credible use of the results of a monitoring effort (UNEP/WHO, 1994a). For instance, elements in the USEPA quality assurance plans (USEPA, 1998b) are: an understanding of the objectives to be met by the monitoring program, personnel training requirements, sampling methods, and sample handling. Standard calibration methods and network intercalibrations are also important issues to be considered (UNEP/WHO, 1994b). The USEPA quality assurance plans also relate to calibration standards, the frequency of calibration of monitoring devices, external performance and system audits (USEPA, 1998b). In this context, important data issues are acceptance criteria, management, archiving, review and evaluation, as well as reconciliation of data reporting with user requirements.

2.3.4 METHODS AND INSTRUMENTS FOR MONITORING AEROSOLS

The principal methods for monitoring $PM_{2.5}$ and PM_{10} involve the collection of aerosol deposits on filter substrates every 24 hours. The filters are weighed prior to and after sampling, following equilibration under defined conditions of temperature and relative humidity (20^oC and 40%, respectively). Because of the long sampling and equilibration times, data obtained by filter methods cannot be used for public reporting, or for measures to protect public health. However, two automated methods are capable of providing near real time, hourly measurements of PM concentrations. They have been designated by the United States Environmental Protection Agency (USEPA) as equivalent methods, based on their performance in comparisons with filtration methods. These are the beta gauge sampler (Wedding and Weigand, 1993) and the Tapered Element Oscillating Microbalance (TEOM) method (Patashnik and Rupprecht, 1991). Data collected using these methods are, for instance, used to calculate the Pollution Standard Index (PSI values in the United States in metropolitan areas with populations over 200,000). Such automated methods represent feasible sampling techniques for operating an effective alert system (UNEP/WHO, 1994c).

Both automated methods are subject to artifacts that result from heating the inlets to temperatures ranging from 30 to 50°C (to avoid interference from the condensation of moisture). The heating tends to drive off semi-volatile components such as ammonium nitrate and some organic compounds. The magnitude of the resulting error in the mass measurement depends, therefore, on the composition of the particles being sampled, which in turn, depends on the nature of contributing PM sources. Under same circumstances, the actual ambient PM mass concentration may be underestimated by such methods, unless site-specific calibrations against gravimetric measurements are performed, thus arguing for caution in ascribing precise quantitative accuracy to the values obtained and associated PSI values.

Other compounds that have less pronounced health impacts, such as SO_2, NO_x, CO, and O_3, should also be measured when plausible. Passive and active monitoring methods for measuring these compounds are described in UNEP/WHO (1994d).

Visibility, Relative Humidity, Precipitation, and Wind Velocity and Direction

Since visibility is a function of the aerosol concentration, it can be used as an indicator for the particle concentration. However, relative humidity and precipitation need to be considered simultaneously as they influence visibility.

Wind velocity and direction are important as they determine how regional haze and smoke pollution levels develop in time and space. The measurement procedures of meteorological parameters are given in the WMO guide (WMO-No. 8).

Solar Radiation

Solar radiometers measure the intensity of solar radiation reaching the instrument. Under smoke and haze conditions, the amount of radiation decreases. In addition to being an indicator of the smoke and haze, the amount of radiation reaching the ground is important for the ecosystem. For instance, a decrease in UV radiation can lead to the overgrowth of certain microorganisms, including ones causing illnesses. Solar and /or UV radiation measurements should be taken from several sites continuously.

2.3.5 DATA COLLECTION, PROCESSING, AND DISSEMINATION

Air quality tends to be highly variable throughout the day due to meteorological factors. Also, when haze is transported into an urban area there is a rapid buildup of PM levels. For these reasons, data collection and processing should be performed on an hourly basis. After air quality data have been collected at monitoring stations, they must be processed and put into a form that can be used by decision-makers. The data are most useful when in electronic format and there is a QA/QC programme for dealing with data transmission, archiving and validation. After processing the data can be disseminated to a data station centre in the governmental agency responsible for taking preventive measures. The data can then be sent to the press or otherwise given to the public.

2.3.6 RECOMMENDATIONS

- ❑ Air quality monitoring should be conducted on a regular basis in major urban and other populated areas likely to be impacted by biomass burning. In addition, stations should be located in rural areas, for background concentration information.
- ❑ The existing networks should be first reviewed and the best sites for monitoring smoke and haze episodes identified. Establishment of additional monitoring stations in areas not covered by the existing networks should be considered. The location of the sites should be determined in accordance with existing guidelines (e.g., US EPA, 1987, UNEP/WHO, 1994a).
- ❑ Participation in international activities such as the Global Atmosphere Watch Programme (WMO, GAW Report No. 113) or the Air Management Information System AMIS (WHO, 1998b) should be encouraged, to maximize the usefulness of data collected by different networks.
- ❑ The institute, and specifically the personnel that are responsible for running the programme and data management, should be identified.
- ❑ Continuity of the programme should be given high priority by the local agencies.
- ❑ In measured compounds efforts should be made to separate the contribution of biomass burning from other sources.
- ❑ Monitoring of aerosol mass ($PM_{2.5}$, PM_{10}), visibility, meteorological parameters, optical depth and solar radiation are of highest priority. At selected sites, targeted chemical quantities such as CO, O_3, NO_x, SO_2, CO_2, aldehydes and other trace pollutants are to be measured.
- ❑ Formulation of uniform protocols for sampling should be established, including temporal resolution and reporting procedures. The establishment of Quality Assessment/Quality Control (QA/QC) procedures for the measurement programme is essential for obtaining reliable and reproducible results.
- ❑ National and regional databases should be established for use of data before, during and after smoke/haze episodes. These data can be used, for instance, in epidemiological studies, planning for future events and for transport modeling studies.
- ❑ The exchange of validated data should be promoted.
- ❑ The different air pollution indices that are used in regional smoke and haze alerts should be harmonized.
- ❑ The data that come from these efforts should be made available for spin-off projects in, e.g., urban environment, emission inventory, acid deposition, climate change and cloud studies.

2.4. SPACE MONITORING OF FIRES AND FIRE RISK

2.4.1. PRESENT CAPABILITY

Fire susceptibility:

Fire susceptibility can be derived from many sources. Among them are the daily images obtained in the afternoon by the AVHRR sensor, on-board the NOAA series meteorological satellites. They orbit the Earth at about 840 km and have a ground resolution of about 1.1km. At least two of these satellites have been kept operational simultaneously in the last 25 years; this same configuration is anticipated in the future.

A quantity known as the "Normalized Difference Vegetation Index" (NDVI) is derived from the AVHRR images and 15-day composite mosaics are used to monitor the vegetation. Different methods exist for generating NDVI values, depending on how many AVHRR channels are used and how they are combined. These values are useful mainly for regions with a marked dry season or phenology cycle, when strong vegetation stress develops. The fire susceptibility risk index is obtained by comparing NDVI values of stressed and normal vegetation. Australia, Brazil, Canada and the USA use such techniques as input in fire risk assessment.

NDVI values are prepared for the land areas of the planet by NOAA, and NASA also generates NDVI databases. The European Space Agency (ESA), in the Monitoring of the Tropical Vegetation group, Ispra, Italy (MTV, 1998) and many regional weather and remote sensing institutions in the world also generate NDVI values. AVHRR receiving stations today cost less than US$10 000, and the images are received at no cost from the satellites, making the use of this technology attractive. Application of NDVI to tropical regions would greatly improve the capability of identifying fire prone regions and vegetation.

In 1998 the National Space Development Agency of Japan, NASDA, launched the satellite for the Tropical Rainfall Measuring Mission (TRMM) (NASDA, 1998). The data from this satellite, combined with rain gauge networks, can be used to assess the precipitation density and from it, the fire susceptibility due to droughts. Although the rain data are available, there is still a need to develop a strategy for using these data for fire susceptibility determination.

Fire monitoring:

Four different types of satellites are currently used to detect fires, although none was designed or is fully fit for this purpose. Nevertheless, the information from these satellites is valuable in regions of the world where poor regional fire monitoring or control exists.

AVHRR images in the mid-infrared band (3.7μm) are particularly sensitive to the temperatures of fires in general and have been used successfully by many countries in different parts of the world (Setzer and Malingreau, 1996). Published field validation of AVHRR fire detection data in Africa, Amazonia (Brazil), Australia, Europe, and Southeast Asia corroborate the high effectiveness of this technique. Brazil, for instance, has had a near-real-time fire detection programme for 15 years, with acknowledged results. Examples of world fire emissions for periods of many months were made at the NASA Goddard Space

Flight Center (SFC, 1998) and at the Joint Research Center (MTV 1998). At least four images per day anywhere in the world can be used, and although the image resolution is about 1.1 km, fire fronts over 30 m will be detected if no water clouds are in the satellite line of sight. Some sections of the images in the afternoon overpasses will present false signals, because of heated soil surfaces (rocks, sand) for some regions in specific seasons.

Application of the data to fire fighting and to monitoring hazards from biomass burning requires real-time processing of the AVHRR images. This can actually be done in the field, or in sites up to 2000 km away, where communication with field personnel is possible. As in the case of the Vegetation Index, reception of AVHRR images is relatively simple and low cost.

Fire detection with geostationary meteorological satellites 36 000 km away (such as GOES) is still in the experimental phase at the University of Wisconsin, USA, and at the National Institute of Space Missions in Brazil (UW, 1999; INPE, 1999; INPE-CPTEC, 1999); only one validation case was reported. The ground resolution of the mid-infrared channel at 4 μm that detects the fires is 4 km, and therefore only the largest fire fronts can be detected. However, the temporal resolution of 30 minutes makes this a unique and mandatory resource for fire monitoring. Geostationary images are received in real time by many weather centers and universities around the globe with stations that require individual decoders. Costs are in the US$ 150 000 range.

The European Space Agency (ESA) operates the Along Track infrared Scanning Radiometer (ATSR) on board the ERS-2 radar satellite (ESA Remote Sensing satellite), that has also been used to detect fires (ESA, 1999). The sensor is very similar to AVHRR, but its mid-infrared band has a lower saturation limit that prevents its use during daytime; another important limitation is that the same site is imaged only once every three days, a constraint in many fire events. Direct observations of satellite signals require investments of significant amounts of money and a good technical staff.

Images of the US military Defense Meteorological Satellite Program (DMSP) satellites have also been used to monitor fires around the globe (DMSP, 1999). In this case only nocturnal images are applicable since the sensor is sensitive to light and not heat. Moon-lit nights preclude use of the images. Reception and processing of the data are restricted and will be done only upon special request through DMSP. Only one case of field validation for vegetation fires has been reported, and the confusion of fires with isolated and non-steady lights is still controversial.

Analysis systems that combine AVHRR satellite fire data with high resolution satellite (Landsat, SPOT, Radarsat) imagery, as well as meteorological and cartographic data, have also been implemented in geographical information systems for use in near real time (USGS, 1999b; Walker, 1996; MIDAS, 1997a; MIDAS, 1997b; CSA/NASA, 1997; CSA 1999a). A leading example in this case is the Brazilian "Proarco" effort for South Amazonia (IBAMA, 1999). Access to this system has facilitated logistical decisions, fire control strategies, and guidelines for policy makers.

Detection of emissions:

The AVHRR sensor was not designed to monitor aerosols. But techniques to measure the aerosol total column loading from AVHRR observations were developed and demonstrated for biomass burning in Brazil (Kaufman et al., 1990). From the AVHRR count of the number of fires and the aerosol loading in $\mu g/cm^2$, the authors estimated the total emission of smoke particles from a group of well identified fires and calculated the rate of emission of smoke particles per fire.

This procedure cannot be applied in every case. It requires the smoke to be transported by wind in a given direction from the fire (which requires wind speed of at least 3-5 m/s), over a dark surface such as water or vegetation. Note that the derived concentrations are of the entire vertical column, rather than ground level concentrations. However, in most cases of large smoke episodes a high pressure meteorological system develops with strong capping inversion and well mixed smoke under it. Therefore the ground concentration should be well correlated to the vertical column concentration. The ratio between the two will depend on the height of the inversion, and that may vary seasonally from one region to another. Regional studies of the ratio of the column concentration to the ground concentration are required to establish this ratio.

Although the applicability of the AVHRR method was demonstrated, there is presently no operational application of the method in any region. Note that the method should be applied manually in every case. To implement the method, the satellite data have to be received by a local receiving station and the necessary software should be in place to analyze and interpret the data. Together with meteorological information, the satellite data can be used to generate a statistic of the number of fires, derive the column aerosol concentration and, with the wind speed, infer the rate of emission of smoke from the fires. Since the AVHRR data for aerosol studies are available only once per day, the diurnal cycle of the fires and smoke should be studied using data from the Geostationary satellites (GOES or METEOSAT). Demonstration of the use GOES was performed at the University of Wisconsin (Prins et al., 1996, 1998). Information on METEOSAT is given by Cresswell (1996).

In some cases it may not be clear if the observed pollution comes from vegetation fires, or whether it is aerosol from urban pollution. To distinguish between them, a combination of AVHRR and Tropospheric Ozone Monitoring Satellite (TOMS) data can be used. TOMS is sensitive to the aerosol absorption of solar UV radiation scattered in the atmosphere. Since the scattering takes place in the whole atmospheric column, absorbing aerosol particles located higher in the atmosphere will have more scattered UV radiation to absorb, and their effect on the TOMS signal will be stronger. Thus, TOMS is not sensitive to aerosols from urban pollution, including sulphate particles, (in the lowest 1.5 km), and the value of the TOMS aerosol index depends on the assumed height of the aerosol. In contrast, AVHRR measures the light scattered by the aerosol particles and therefore measures both smoke and urban pollution. But since sulphate particles do not absorb solar radiation, TOMS and AVHRR data permit smoke to be distinguished from urban pollution.

Neither AVHRR nor TOMS data can be used to estimate the aerosol size distribution, even though both are sensitive mainly to sub-micrometre aerosols.

TOMS data are designed to monitor tropospheric ozone, using a method similar to that described for monitoring aerosol. Here also an assumption on the vertical distribution of ozone has to be made. The accuracy of results depends heavily on this assumption.

2.4.2 CAPABILITY 1-2 YEARS FROM NOW

Fire susceptibility:

Many new remote sensing satellites and sensors are scheduled to be launched in the next two years by Brazil, Canada, China, Europe, India, and also within the frame of multi-national cooperation. Their data should increase the spatial, radiometric and temporal resolution of values indicating vegetation stress and fire risk. An improvement in the fire risk prediction is therefore expected, although along the same scientific rationale developed from the pioneering AVHRR work.

Because of these new satellites, the time needed to gather enough data on the vegetation cover over most of the planet may be reduced from 15 days to 10 days (without cloud cover or poor imaging conditions), and with a ground resolution of a few hundred meters. Institutions currently providing vegetation stress data derived from satellites are preparing the algorithms and processing of future data; from an user point of view only the capability to receive the new data via Internet should be upgraded.

The new satellites and sensors will also provide estimates of burnt areas, most needed information for evaluating the impact of fires in terrestrial and atmospheric environments. At present some efforts are being done in this direction by groups in Brazil (INPE) and in Europe (JRC, Ispra), also using AVHRR data. NASA (Goddard SFC) is pursuing the subject for future 250 m resolution data using the Moderate Resolution Imaging Spectro-radiometer (MODIS) facility on the TERRA (formerly EOS-AM1) satellite (SBRS, 1997; NASA, 1999a).

A significant change is also expected in the integration of remotely sensed data and data from ground monitoring; these include vegetation types, vegetation stress, meteorological and weather variables, topography, soil types, soil moisture, etc. Powerful Geographical Information Systems (GIS) are being developed and should be available for fire risk assessment, management and control. Skilled and trained technicians will be needed to operate and extract useful output from such sophisticated means.

Fire monitoring:

Two satellites with appropriate sensors for fire detection are to be launched in the next two years, adding new possibilities in this field.

TERRA/EOS-AM1, scheduled for August 1999, with an expected life time of six years, will produce images very similar to those of AVHRR in terms of area coverage (about 2200 km swath) and ground resolution (about one kilometre). However, its 36 channels have a much higher saturation temperature limit in the thermal bands and will greatly improve current AVHRR capabilities (Kaufman et al., 1998). Radiation energy, which is related to the fire temperature and size, will be estimated; and confusion due to sun glint or exposed soils that occasionally impair parts of AVHRR images will be eliminated. One limitation, however, must be considered: AM1 overpasses will be around 10:30 (a.m. and p.m.), and therefore will miss most of the short duration fires of anthropogenic origin that are started early afternoon, at the peak of the daily temperature cycle.

The German Aerospace Center (DLR) is building a pilot satellite named BIRD, specifically designed for real-time fire detection. It is to be launched in 2000 and its expected lifetime is about 2 years. One wide-viewing camera in the satellite will identify fires, and a narrow-viewing camera will concentrate on specific fires. Access to the data will be free and will require special receivers and stations. Full details of the operational mode of this satellite are available from DLR (1999).

Detection of Emissions:

The detection of emissions will be similar to that presently available with AVHRR, but in addition it will be possible to use the MODIS and the Multi-angle Imaging Spectro-Radiometer (MISR) data (SBRS, 1997; JPL, 1999). The fire and aerosol detection will be enhanced in several ways:

(a) MODIS will not only measure the fires to a resolution of one kilometre, but will also indicate the value of the radiation energy emitted by the fire. The energy is a measure of the fire strength or the rate of consumption of biomass by the fire.

(b) MODIS and MISR are designed specifically to monitor aerosol. Their data will be used directly to derive the daily aerosol concentration with a resolution of 10-20 km. The fire and aerosol data will be generated and archived daily on a global basis within 48 hours of the data acquisition. It is possible that in the first year after launch only a fraction (20-40%) of the data will be available.

MODIS data from imaging over the ocean can be used to estimate the ratio of the concentration of the micrometre size mode to the sub-micrometre mode. The mass concentration in each of the modes will be routinely derived from the MODIS data and archived.

MODIS will have a direct broadcast capability. It is recommended that local receiving stations and NASA analysis software be acquired to produce local real-time data sets on fire occurrence and aerosol emissions.

As with AVHRR and TOMS, MODIS and TOMS can be used to distinguish between smoke and urban pollution.

EOS-AM1 will also include a Canadian instrument for the Measurement Of Pollution In The Troposphere (MOPITT), to measure the concentration of CO in three altitude ranges of the atmosphere, as well as the total column concentration of CH_4. The ranges are: 0 to 3 km, 3 to 6 km, and over 6 km. Similar to aerosol data, this information can be used to derive the rate of emission of CO and CH_4 from the fires. MOPITT will not have a direct broadcast capability. The data on CO and CH_4 will be accessible from the NASA archives within 48 hours after acquisition (CSA, 1999b).

2.4.3 LONGER-TERM PLANNED CAPABILITY

In late 2000 or early 2001 NASA plans to launch the second EOS satellite – EOS-PM1 for an afternoon orbit with observation at 1:30 pm local time. It will also have on board the MODIS instrument with the same capability as the instrument on AM1, thus providing an additional and timely observation of smoke and fires every day.

The German Aerospace Center (DLR) and the European Space Agency (ESA) are working on a second fire detection satellite, FOCUS (DLR, 1997), an improvement over BIRD. The DLR Innovative Infrared Sensor System FOCUS is to be flown as an early external payload of the International Space Station (ISS, NASA, 1999b) with:

- forward-looking imaging IR sensor with a direct link to a processor dedicated for near-real-time, on-board autonomous seeking, detection and selection of hot spots.

- high resolution IR-spectrometer / IR-imager sensor combination for remote sensing high-temperature event gas emissions. The data allow the burning efficiency and emission factors of vegetation fires to be estimated, as well as those of volcanic gas emissions. FOCUS was selected by ESA as one of five European ”Groupings” to be flown as an external payload in the period 2003 – 2005 and is now running in Phase A.

There are also plans for the launch of an advanced geostationary satellite with a fire detection capability down to one kilometre resolution, thus enabling accurate fire detection every 30 minutes throughout the day and night. This will be the ultimate remote sensing detector of fires, but technical limitations still need to be solved in this case.

In 2001 NASA also plans to launch the first polar orbiting satellite with a lidar system – the Geoscience Laser Altimeter System – GLAS (NASA, 1998). Lidar units include a laser and receiver/detection system that can profile the vertical distribution of the smoke and the height of the capping inversion. Although MODIS and GLAS will not be in the same orbit, their combined data enable a better estimate of the ground concentration of the smoke aerosol.

2.4.4 IMPLEMENTATION RECOMMENDATIONS

Coordinating the fire activity

Satellite data are available for monitoring fires and smoke aerosol. Additional satellite sensors will be available within the next 1-2 years. It is recommended that a centre of excellence in fire and smoke monitoring be established. The centre should be familiar with the technology and with the available software to analyze the satellite data. It would be responsible for overseeing both the regional estimates of fire emissions and the regional validation of the smoke and emission analysis from satellite data. The centre can be structured similar to the FIREGLOBE monitoring centre (GFMC, 1999a). It should develop new strategies for fire and smoke detection, and it should advise the international bodies and agencies of its needs. It would also integrate the ground-based, aircraft and satellite information. It would work with regional centres (described below), disseminating information and new technology to them, as well as coordinate the training of technicians to handle new fire emissions and software.

The development and establishment of a scale to grade the severity of on-going fire episodes is also an important step to be undertaken. Such an indicator could combine satellite data about the number of active fires per unit area, the size of the areas burning and the energy released by the fires, with the extent of smoke palls and the concentration of pollutants in them. Current scientific and technical knowledge allows the definition of such indicators.

Also recommended is the development of a space fire-monitoring system, comprising fire-detection satellites and real-time portable receiving hardware to provide information on the location of active fires, smoke, and trace gases emitted from the fires. The measurements should represent the diurnal cycle. The information generated by this system should be provided to the affected countries and localities in near real-time, in a simple and inexpensive manner; if possible, directly from the satellite to local users.

Regional fire activity centres

On a regional level there is a need for fire activity centres. These centres will receive the regional satellite data using their own receiving stations, and integrate it with meteorological information and the ground and aircraft monitoring efforts. The centres will use the data to monitor the development of the fires and smoke and predict the spread of the smoke. The centres are needed since the biomass burning changes from region to region, and since direct reception of the satellite data is essential for real time operation. Since there are already WMO centres or representatives with satellite and meteorological capability, they are natural candidates for the location of the regional fire activity centres.

Data availability

The recommendation is to approach NASA and other appropriate agencies to continue placing relevant data on the Web. For example, the global coverage images of the TOMS aerosol index and the NDVI.

Data receiving stations from the MODIS instrument are not yet well developed. This issue requires attention in order to have affordable receiving stations.

Software development

Software packages and instruction material for using the satellite data need to be developed, to allow warnings of smoke impacts and analysis of smoke concentrations.

It is recommended that a smoke assimilation model be developed that uses global circulation models, enhanced with local meteorological data and simple smoke mass-balance equations. The model should be initiated by the density of the fires, or the fire radiation energy, and fire emission factors. It should be updated on a regular basis using satellite data on the presence and spread of smoke.

Validation

Reliability of fire emission estimates from remote sensing should be ensured by continuous validation, using both ground based *in situ* and remote measurements in areas where severe health problems are known to occur as a result of extensive and intense fire episodes. Such validation will enhance the usefulness of satellite data as input to the simulation model. Once developed, they will also help determine the environmental hazards for human health.

A ground-based network of air samplers (air pumps and filter holders) is necessary to measure the concentration of aerosols for sizes under 2.5 μm in diameter.

2.5 CLIMATE MONITORING AND MODELLING THE DISTRIBUTION OF FIRE EMISSIONS

The distributions and concentrations of fire emissions must be described by the calculation of atmospheric transports using models designed for this purpose.

The task of describing the spatial and temporal distributions of fire emissions is divided into determinations, which can be made:

- before the event;
- during the event; and
- after the event.

Defined goals are to be achieved in each of those three stages of the event.

2.5.1 BEFORE A MAJOR FIRE EVENT – IDENTIFICATION OF FIRE RISK

Before the occurrence of any major episodic fire, national or regional centres need to carry out preparatory studies that will serve both as early warning indicators and provide the framework for monitoring fire plumes when and if major fires occur. Such preparatory studies can be partitioned into spatial and temporal components.

Space

The historic distribution in space of major fire episodes needs to be determined for each region. An effort should be made to:

- identify past major fire events for the region.
- define a major fire event in terms of the magnitude of emissions (mass, concentration, extent)
- obtain as long a record as possible of these major events.

The spatial distribution of major fire events in the regions should be correlated with climatic controls in the region. Climatic information on the spatial distribution of rainfall, drought or fire indexes should be correlated with the historic record of major fires.

Time

The temporal distribution of major fire events in the region should be determined on inter-annual, annual and seasonal time scales. Particular attention should be paid to time intervals corresponding to known climate oscillations, such as the El Niño – Southern Oscillation (ENSO) events (NOAA, 1999).

Seasonal and annual predictions, or monitoring, of such important phenomena as the ENSO should be related to the observed historic occurrences of major fire events in the region.

On shorter time scales, including daily monitoring, full use must be made of existing fire-prediction systems. These systems usually include:

- drought index
- number of dry days
- readings of relative humidity
- vegetation index
- air quality index

A number of these measurements are now available from satellite-borne sensors.

Large-scale transport models

A history of regional atmospheric conditions, typical of the major fire events identified above, should be compiled. Such prototypical atmospheric conditions should be used to calculate long-range trajectories (up to 10 days) from the points of occurrence of major fires.

These long-range trajectories should be computed for a series of levels in the atmosphere (e.g. 850, 700, 500, 200 hectoPascal) and used to establish:

- the most likely transport pathways
- centres of population at risk
- optimum locations for surface monitoring sites
- indicators of transport times
- indicators of the likelihood and location of re-circulation and increased concentrations
- indicators of the persistence of polluted conditions.

Large-scale transport calculations can be carried out using existing trajectory models at national, regional or WMO meteorological centres. Such models should be exchanged between centres to resolve any inconsistencies between them and to standardize procedures before any major future fire event occurs. Information can also be used in determining locations for ground based monitoring sites.

2.5.2 DURING A MAJOR FIRE EVENT – PROVISION OF TRANSPORT MODELLING DATA TO EMERGENCY RESPONSE AGENCIES

Once a fire has reached a threshold that triggers a full-scale emergency response, a critical component of the emergency response will be to provide information on likely emissions impact areas downwind of vegetation fires and, if possible, information on pollution concentrations. Atmospheric Transport Modelling (ATM), based on assimilated observations and Numerical Weather Prediction (NWP) models, is the most useful approach for determining the local and regional impacts of vegetation fires. These predictions must be readily accessible to the emergency response agency.

This activity could be undertaken by national or regional meteorological services that have the capability. WMO has a network of Regional Specialized Meteorological Centres (RSMCs) that provide meteorological support during environmental emergencies associated with nuclear or radiological accidents (WMO-TD/No. 778). These centres have full atmospheric transport modelling capability (global and regional area modelling capability along with a fully integrated ATM). Each centre is responsible for providing advice in their region in the form of a basic set of products, which includes the prediction of trajectories for release at specified heights, atmospheric exposure and surface deposition.

Acquisition of Data for ATMs

The nominated meteorological agency will provide the meteorological information and NWP outputs for use in their ATMs, at time and space scales consistent with current modelling capabilities and emergency response requirements. For modelling the trajectory and relative concentrations the best possible current information on locations and areas of fires is required, along with the heights of emission release, if possible. This information is currently available from satellite remote sensing. Detailed concentration modelling requires additional information on the emission rates of particles (or other pollutants), particle size distributions, and deposition rates that is not yet routinely available.

Trajectory and Dispersion Modelling Using ATM

The nominated meteorological agency will provide the best possible information to the emergency response agency on transport trajectories and pollution dispersion from the vegetation fire. Trajectories can be run forward in time to determine receptor areas, or backwards in time to determine pollutant source areas. Relative concentration modelling, requiring limited input data, will provide information on the spatial distribution of likely pollution impact.

The transport modelling that is undertaken should be consistent within forecasting errors, suggesting that transport forecasts should not extend beyond 3-4 days. Transport modelling should also be continuously updated during the episode, using assimilated observational data (as distinct from forecast data).

Validation of Model Output

During the fire emergency there should be continuous qualitative and quantitative validation of the model output. Verification of the general smoke patterns and trajectories predicted by ATMs can be performed using satellite, aircraft and ground-based data. Transports based on assimilated observational data can be compared with the equivalent forecast transports. This is sufficient for relative (qualitative) modelling. However, for health applications, and when absolute concentration modelling is attempted, quantitative modelling will be needed. In this case, the determination of emission rates as a function of particle size, emission area and height, and measurements of airborne concentrations and surface depositions, will be needed.

2.5.3 AFTER A MAJOR FIRE EVENT- REVIEW OF TRANSPORT MODELLING DATA AND ITS PROVISION TO EMERGENCY RESPONSE AGENCIES

After the fire episode is over, the overall performance of the models and their use should be evaluated:

- The model(s) performance should be validated against measurement and satellite data
- If several models were used, did they give similar results?
- Did the modelling results reach the intended audience?
- How was the information used?
- Was the audience satisfied with the information they received?
- What needs were not addressed?

2.5.4 RECOMMENDATIONS

- To identify in each region the responsible agency capable of carrying out the complete suite of tasks associated with climate monitoring and modelling of the distribution of fire emissions. These capabilities must include:
  - Utilization of historical fire and climate data, to produce spatial and temporal distributions of major fire events.
  - Production from the historic record of an assessment of fire prone areas and times for each region.
  - Development from the historic record of a description of: the most likely transport pathways and times; the population at risk of exposure on these pathways; optimum locations for surface monitoring sites; areas where re-circulation and concentration of fire emissions occur and where high concentration of fire emissions may persist.
  - Development of a verification database for long-range transport and dispersion models, including access to global model-generated databases.
  - Predictions of climate change, including knowledge of periodic changes, ENSO/climate variability, and seasonal-to-daily changes in variables such as the drought index, to anticipate fire potential locations and times.
  - Installation of trajectory and dispersion modelling capabilities, using state-of-the-art models most applicable to the region.
- To upgrade and install emissions monitoring systems, including access to satellite-generated remote-sensing measurements.
- To carry out model verification studies including:
  - dry run studies.
  - comparisons between dry runs and ground and satellite-based observations.
  - comparisons between, and standardization of, products developed by different agencies for the same case studies.
  - test runs of the complete emergency response system in each region, to determine that real-time products reach the user groups in a useable form and in timely fashion.
- To finalize capabilities for producing model-generated descriptions and predictions of the distribution of fire emissions, by providing clear documentation of the capabilities and products to all user agencies in the respective regions.
- To carry out post-event evaluation of both the climate monitoring and modelling capability, including comparisons with satellite and ground-based observations, as well as user satisfaction with the materials provided. The systems should be updated as required.

2.6. EMERGENCY RESPONSE PROCEDURES

2.6.1. INTRODUCTION

A strong prevention programme is a prerequisite for effective fire emergency management. It requires regular monitoring of fire and other haze-causing sources, of air quality and visibility and of meteorological and weather conditions. It also requires the building of advanced prediction and early warning systems. The necessary management must be in place in terms of legislation, institutional arrangements, financial resources, and technical support. Such a set of strategies has to be supported by clear objectives and guided by consistent policies.

This review is largely based on various national haze action plans of ASEAN member-countries and the Report of the ADB-ASEAN Preparatory Meeting on National Haze Action Plans, held in Manila, Philippines, 8 - 9 June 1998. It covers policies and strategies for assessment and management, particularly those concerning emergency response mechanisms and possible legal issues. It also highlights the need, not only to address the causes and impacts of fire as external sources of haze and pollution, but also to take into account the local pollution, particularly those places impacted by the vegetation fires.

2.6.2. POLICY REVIEW

As summarized in the outline below, most countries, particularly in the Southeast Asian region, have introduced their respective policies as part of their national action plans to prevent and mitigate land and vegetation fires.

The most common policy objective of the region is “to prevent and control fire and haze,” with minor variations in emphasis among seven of the eight ASEAN countries. But only four countries have introduced and enforced policies strictly prohibiting open burning: Malaysia, Myanmar, Philippines and Singapore. In Brunei Darussalam, the prohibition is enforced only during the dry period. Such a policy is highly recommended for the other countries in the region.

Indonesia sets itself higher policy objectives by introducing the development aspects of its policy. A specific policy objective is to establish land conversion targets, set at sustainable levels. Implicitly, areas are set aside that are invaluable in bio-diversity, and mitigation measures for those communities at risk from vegetation fires and haze are only marginal. Fire management is quite focused and narrows down to the need for effective fuel management through controlled burning. But it is silent on the timing of such a practice, especially with respect to practice in dry periods.

On the need to address other local sources of haze and pollution, five countries, namely, Brunei Darussalam (Br), Malaysia (My), Philippines (Ph), Singapore (Sg) and Thailand (Th), have established and enforced their respective emission standards for motor vehicles, industries and other domestic sectors. Controlling local sources of pollution, particularly during the haze episodes, is equally critical to safeguard public health and safety and other environmental concerns.

On the assessment aspect of the Policy framework, six ASEAN countries, not including Indonesia (Id), have emphasized the need for ambient air monitoring and reporting. Monitoring and reporting are basic to assessment and management functions. In addition, Brunei Darussalam sets itself "to determine the source of haze", while the Philippines wants "to determine health hazards", as part of the assessment aspect of their respective policies.

On management, greater focus is needed to introduce and strengthen legal and institutional arrangements at both national and regional levels. Six ASEAN countries, not including Brunei Darussalam, have emphasized the capability and capacity for regional co-operation, particularly in the deployment of fire fighting resources. The need to provide the public and other relevant entities information on the episodes and responses is important. This has been specifically emphasized, at least by three countries: Brunei Darussalam, Singapore, and Thailand. Management specifics that are relevant to others have been introduced by certain countries:

- to establish incentives to use degraded land (Id).
- to substitute slash and burn methods with sustainable cultivation techniques (My).
- to promote the utilization of agricultural wastes (Th).
- to provide infrastructure for collection and disposal of solid wastes (Sg).
- "to minimize haze, pollution by fuel management" through controlled burning (Id).

A Summary of National Policies Relating to Haze in the Southeast Asian Region

POLICY OBJECTIVES

A. To prevent and control land and forest fires and resulting air pollution (Br, Id, Ma, My, Sg);
To prevent and monitor haze/transboundary air pollution (Ph);
To mitigate, minimize the environmental and health impact from the Indonesian forest fires (Th);
B. To safeguard public health and safety (Br);
C. To prohibit open burning (My, Ph, Sg);
D. To control emissions from mobile and stationary sources (Br, My, Ph, Sg, Th);
E. To introduce provisions of ambient air quality guidelines and standards (Ph);

DEVELOPMENT OF POLICY:

A. To set land conversion targets at sustainable levels (Id);
B. To protect communities and valued ecosystems at risk from the effects of fire and haze (Id);

ASSESSMENT:

A. To obtain information on the state of air quality (Br);
To monitor air quality (Br, My, Ph, Sg, Th) and report on air quality (My, Ph, Th);

B. To determine source of haze (Br);
C. To monitor smoke and particle emissions from mobile and stationary sources (Ma);
D. To determine health hazards (Ph);
E. To promote vigilance measures (My);
To carry out surveillance to prevent and detect fires (Sg, Th);

MANAGEMENT:

A. To provide the public and authorities with information on air quality and the action taken (Br);
To promote public awareness, education, and feedback (Sg, Ph, Th);
B. To ensure adequate medical and health facilities (Br);
C. To provide considerable support to neighboring ASEAN countries (Th);
To promote cooperation among Asian countries (Ph);
D. To minimize haze pollution by fuel management (Id);
E. To strengthen interagency collaboration (My, Sg, Ph, Th);and to mobilize resources to strengthen the capacity of agencies responsible for the plan (My, Sg, Th).

2.6.3. EMERGENCY RESPONSE MECHANISMS

A review of the aspects and components of existing "emergency" response mechanisms, at both the national and sub-regional levels within the Southeast Asian region, provides a basis for formulating an overall response mechanisms for the region. Essentially the required mechanisms (Figure 2.6.3-1), involve the following functions in decreasing order of priority:

- Early Fire (Hot Spot & Smoke) Detection
  - Satellite Monitoring
  - Aerial Surveillance
  - Ground Surveillance
  - Weather Forecasting
  - Surface-based Atmospheric Modelling

- Fire Fighting
  - Coordination at national level
  - Coordination and assistance at sub-regional level
  - Action at local level

- Communication Links
  - Internet
  - Intranet
  - Telephone/Telefax
  - Radio

- Enforcement

- Public education and awareness campaigns
- Air quality monitoring
- Studies of health and other socio-economic impacts
- Fire danger rating
- Land-use planning

The need for international and regional cooperation in exchanging satellite data, as well as those from air-borne and ground surveillance, is implicit in the plan. Such data will provide a basis for national and regional authorities to prevent and control forest fire incidents. This co-operation is to be conducted with technical assistance from all centres of excellence, particularly for weather forecasting and for modelling long-range transport of haze. Timely forest management is critical in ensuring the success of any emergency response plan.

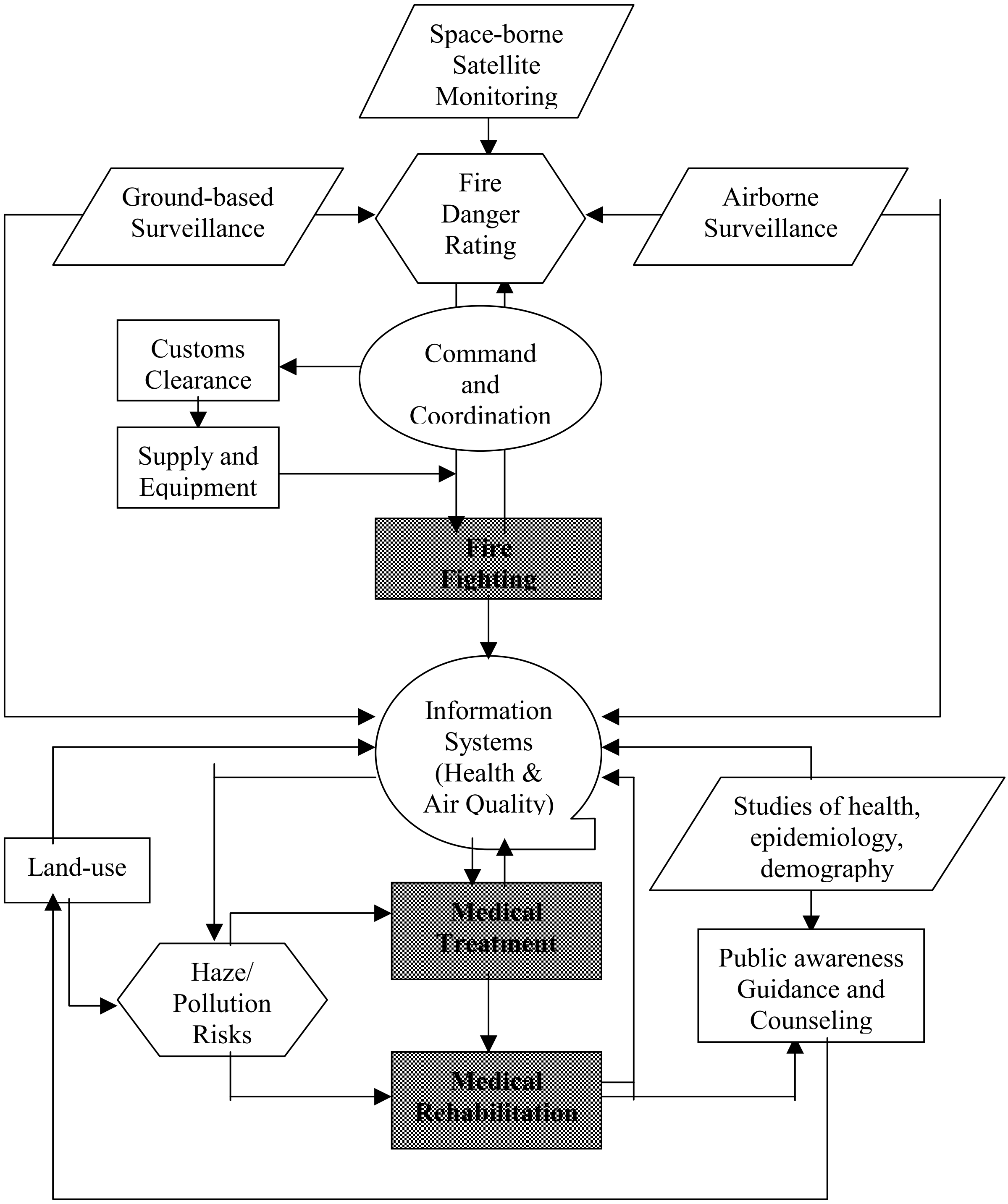

Figure 2.6.3-1 Schematic diagram of the essential emergency response mechanisms

2.6.4. OTHER POSSIBLE LEGAL ISSUES

It is generally anticipated that no legal issues at the regional level will arise from the execution of the emergency response plan. This relates particularly to the mobilization of vessels, aircraft, equipment, and personnel across national boundaries, as such activity has been pre-planned; a standard operating procedure (SOP) is put in place especially for customs and immigration clearance.

However, some legal issues are anticipated at national levels, as various authorities implement or activate their National Haze Action Plans (NHAPs) during an episode. As external sources of haze or pollution are beyond their control, national authorities have to reduce, control, and even prohibit certain internal polluting activities during the episode. Such an action will certainly have both financial and economic implications.

Most countries have general or specific laws and regulations both for controlling vegetation fires and air pollution and to protect public health and the environment from the impacts of these sources. As an example, the specific laws and regulations in Malaysia come under the Environmental Quality Act (1974, Amendments 1996) and include:

- Environmental Quality (Clean Air) Regulations 1978 – setting emissions standards for stationary and mobile sources;
- Environmental Quality (Amendment) Act 1998 (Act 1030) - introducing provisions prohibiting open burning;
- Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 1987.

There are many other laws and provisions in Malaysia that are applicable to the control and mitigation of land and forest fires, and air pollution. These include acceptable practices in forest management, land development, solid waste disposal, etc.

To complement regulatory measures, it is good policy for those responsible for air pollution to exercise "self-regulation" in response to a worsening condition of the environment, without having to rely on directives from the authorities.

2.6.5. SUMMARY

Many, if not most, countries have already established to some extent policies, legislation and emergency response measures to control and combat vegetation fires and air pollution, and to minimize the impacts arising from these occurrences. For this reason, the development a common set of Health Guidelines for the interest of all the countries involved is most timely. To ensure that the objectives of these Guidelines can be achieved, mechanisms for providing assistance to the respective countries are most important, and should include Guidelines into their existing policy, legislation and emergency response. Areas of inadequacy can thereby be identified and strengthened.

In terms of policies, the essential elements to be incorporated can be extracted by combining approaches developed by the individual countries. The elements identified are:

- To prevent and control land and forest fires
- To safeguard public health and safety in such an occurrence
- To prohibit open burning
- To introduce and implement ambient air quality guidelines and standards
- To strengthen controls on emissions from mobile and stationary sources

The elements with respect to Policy on Development are:

- To set land use planning, based on sustainable development principles
- To protect communities and ecosystems at risk from fire and haze effects

The elements with respect to Policy on Assessment include:

- To monitor and report on air quality
- To develop an effective mechanism for monitoring land and forest fires
- To develop the capability to detect and predict forest fires and haze
- To monitor the health and environmental impacts of haze

The Management Policies focus on the following aspects:

- To provide the public and authorities with information on air quality and action to be taken
- To advise the public on action to be taken for health protection
- To ensure medical supplies and facilities to mitigate health impacts
- To provide support to countries in need and to promote cooperation among Asian countries
- To minimize haze pollution from fuel burning
- To strengthen capabilities of the relevant agencies
- To strengthen interagency cooperation and support

Most countries have in place some form of laws for the control of forest fire and air pollution and for protecting public health and the environment. The present needs lie in identifying areas of weakness and establishing the means to strengthen enforcement. A framework for the formulation of emergency response mechanisms can be derived from the cooperative experience among the three countries most affected during the 1997 haze episode, namely Indonesia, Malaysia and Singapore. The framework encompasses coordination activities, monitoring and detection of fires, fire fighting, communication channels, enforcement, monitoring of air quality and health impacts, public education and awareness campaigns, and land-use planning and fire-danger rating.

The success of any policy will rest on the timely exchange of data and experiences, possibly by electronic means or by teleconferencing, among various national, regional, and international authorities or centres of excellence, and on their close co-operation and continuing support.

2.6.6 RECOMMENDATIONS

- This section of the Guidelines should continue to be updated and expanded to interpret the experiences of regions other than Southeast Asia.

- To protect fire-hazard and haze-sensitive subgroups of the population, a health guideline should be developed, advance warning should be provided, and provisions made for translocation of such groups as a preventive health measure.

- Institutional arrangements at international and regional levels need to be developed and used, similar to those of the ASEAN Specialized Meteorological Centre, for advanced warning of meteorological conditions that lead to a haze-episode. Such early warning capability is invaluable to national authorities trying to enforce strict controls on both controlled and open burning of any form of biomass or waste.

- As a follow-up to such early warning an infrastructure for ambient air monitoring, similar to that of privatized monitoring networks in Malaysia, should be located downwind of areas prone to fire and in communities likely to be affected.

- For the communities affected by both vegetation fires and other sources of pollution, a series of guidelines needs to be developed to protect public health not only from the impacts of particles, but also from other health-affecting pollutants, in particular sulfur dioxide, ozone, and carbon monoxide.

- During a fire event, national authorities should consult competent international bodies, including WHO, WMO, and UNEP for advice. These international bodies should investigate the feasibility of establishing an ongoing panel of experts on haze, whose members are linked via electronic media for the rapid exchange of data.

2.7 HOW TO USE AND APPLY THESE GUIDELINES

The following sections list measures which should be undertaken before, during and after fire events.

2.7.1 PRE-EVENT ACTION

- International organizations, such as WHO and WMO, should make efforts to motivate national authorities so that they integrate these Guidelines in their emergency planning.

- At the national level, the responsible authorities (Ministry of Health, Ministry of Environment) should identify an Emergency Task Force, to include a Vegetation Fire component in their National Health Sector Plans, or to create a Plan for Vegetation Fire Emergencies.

- Coordinate multidisciplinary meetings to elaborate the "Response Planning," including:
  - fire fighters (prevention and control)
  - health services (health centres and hospitals)
  - epidemiological surveillance unit
  - environmental surveillance networks
  - environmental monitoring and meteorological services

- These Response Plans must:

  - Identify general responsibilities, technical aptitudes, experiences and human resources of each sector

  - Divide the Plan into three blocks:
    - Pre-Event measures and Early Warning
    - During-Event measures: Response and assessment of damages and needs
    - Post-Event: Evaluation and update of the plan, including dissemination of lessons learned

- Define Information Sources:
    - Public health epidemiological surveillance
    - Air quality monitoring
    - Meteorological surveillance
    - Satellite data

- Evaluate availability and quality of information

- Evaluate needs for complementing information sources (frequency, additional monitoring, other techniques, new investigations, etc.)

- Evaluate needs of training and financial sources;

- Identify baseline levels for health and air quality

- Describe the responsibilities and actions of each agency in vegetation fire emergencies

- Define coordination and information flow between different agencies

- Define Risk Communication with:
  - Authorities
  - Mass media
  - Public

- Call upon other relevant entities to improve the response planning with their contributions

- Training teams, simulations and coordination exercises

- Replication of the plan at regional and local levels

- Budget and resources planning

2.7.2 DURING-EVENT ACTION

Response to, and assessment of, damages and needs:

- Evaluation of surveillance systems
- Compare information during the event with baseline information
- Mitigation
  - Public advice and awareness
  - Evaluate the capacity of the Public Health System to provide services, and reinforce its human resources, pharmaceutical and other needs

2.7.3 POST-EVENT ACTION

- Critical evaluation of measures taken during the event

- Evaluation of the impact of the fire event on public health and the environment

- Evaluation of the socio-economic impact

- Updating and improving the plan for vegetation fire emergencies

- Dissemination of lessons learned

3. GUIDELINES ON VEGETATION FIRE EMERGENCIES FOR PUBLIC HEALTH PROTECTION

3.1 INTRODUCTION

While the prevention of unmanaged vegetation fires is the most desirable method for protecting public health from fire-related air pollution, this section will focus on the responsibilities of authorities (Ministry of Health, Ministry of Environment). This emphasis assumes there is a need for guidelines in the event of a fire. Protection of the health of firefighters is discussed in detail elsewhere (Sharkey, 1997). The information in this section can also be used by authorities as a means of motivating better land management and fire prevention practices within the government, by indicating the serious health impacts that may be associated with fire-related air pollution.

3.2 HEALTH EFFECTS

3.2.1 OVERVIEW OF THE HEALTH EFFECTS OF SMOKE FROM BIOMASS BURNING

Key areas to be considered in the evaluation of health impacts are the level and duration of exposure, as well as the susceptibility of the affected populations. In understanding the potential population health effects, it is important to note that, in general, the more serious the health endpoint (e.g. mortality, morbidity, symptoms, functional changes), the smaller the affected population will be. In turn, the more serious the health endpoint, the greater the availability of data. The pyramid below (Figure 3.2.1-1) illustrates this concept for several of the more important health endpoints associated with air pollution. The size of each level in the pyramid represents the proportion of the population affected. Severe outcomes such as mortality will only be experienced in a relatively small group of people, while less severe outcomes, such as reduced lung function, will generally be evident in a larger segment of the population.

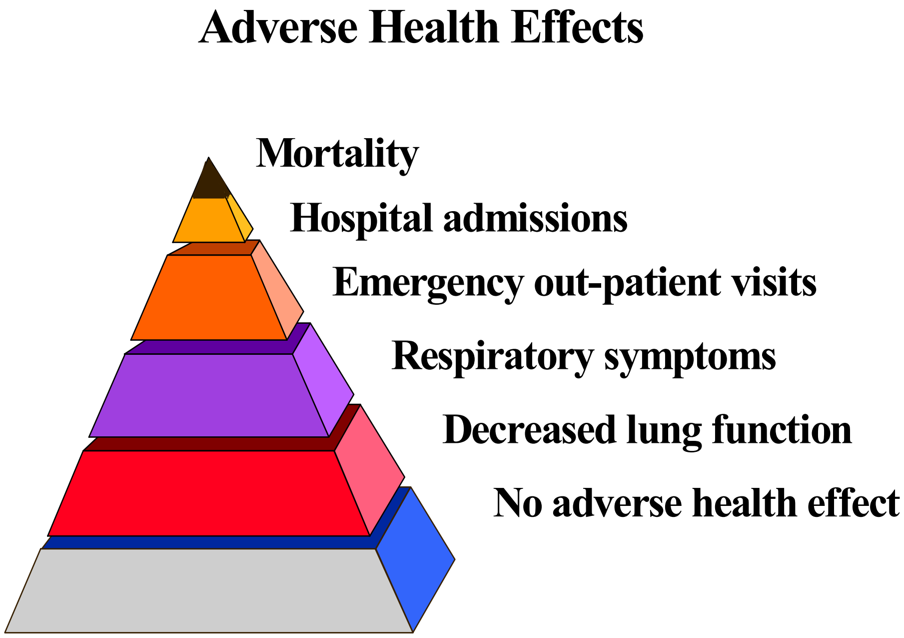

Figure 3.2.1-1 Health effects pyramid

Biomass smoke contains a large number of chemicals, many of which have been associated with adverse health impacts. These include both particles and gaseous compounds. Particulate matter is itself a complex mixture associated with a wide range of health impacts. Little is known about the toxicology of biomass smoke, but epidemiological findings correlate most consistently with particulate matter. Exposures to high concentrations of carbon monoxide and other pollutants are highly variable and are only occasionally observed in individuals, such as wildland firefighters and people who cook with biomass fuels. Literature reviews of the exposure and health impacts, as well as evaluation of data from regions impacted by fire-related air pollution, indicate that particulate matter is the pollutant most consistently elevated in biomass smoke. Accordingly, the emphasis throughout this section of the guidelines will be focused on particles. Since PM_{10} is most commonly measured, this section will refer to PM_{10}. However, the $PM_{2.5}$ fraction is more likely to reflect the particles produced during fires, while the PM_{10} fraction will include additional particles from resuspension of soil and ash. When the contribution of these additional particles is not significant, PM_{10} is a good indicator of $PM_{2.5}$ from vegetation fires. $PM_{2.5}$ is more relevant for assessing health impacts, as this fraction efficiently infiltrates indoors, where most exposure occurs, and is inhaled.

The highest concentrations of particulate matter occur with indoor biomass combustion in developing countries, and with wildland firefighters. These levels are 10 – 70 times above those observed in urban areas (WHO, 1992a). PM_{10} levels can amount to several thousand $\mu g/m^3$. Lower concentrations have been observed in ambient air within communities where wood burning is common and in plumes associated with large-scale tropical forest fires. These levels are 2 – 15 times those observed in urban areas (Brauer, 1998). Domestic biomass burning in developing countries has also been associated with extremely high polycyclic aromatic hydrocarbon (PAH) levels (1000 times levels in urban air) (Brauer, 1998). Ten-fold lower exposures to PAH have been measured close to vegetation fires, and in communities with extensive smoke emissions from indoor wood burning. Exposures to high concentrations of carbon monoxide are highly variable and only occasionally observed with wildland firefighters and those exposed to domestic biomass smoke.

Several groups expected to be more susceptible to the health impacts of biomass smoke include the very young, pregnant women, the elderly and individuals with pre-existing respiratory (asthma, chronic obstructive pulmonary diseases) and cardiac diseases. Other groups may be more susceptible due to higher exposures: outdoor workers, firefighters and emergency response workers. Mitigation measures should be focused first on the most susceptible members of the population.

Below, studies indicating a relationship between exposure to biomass smoke and adverse health will first be described. Epidemiological studies on the health impacts of particle air pollution will also be assessed. Such studies allow a quantitative assessment of the health impacts on the general population that are associated with exposure to smoke or haze from vegetation fires. By analogy with urban studies that associate increased mortality with particle air pollution, it is reasonable to conclude that similar findings would also be observed in non-urban locations where people are exposed to biomass smoke. From the vast number of epidemiological studies on particulate matter, there is no evidence that airborne particles from different combustion sources have different impacts on health. Therefore, there is little reason to expect that particles from biomass smoke would be any less harmful than other combustion-source particles. It is prudent to consider that biomass smoke exposure is also related to increased morbidity and mortality. Studies investigating the association between morbidity and mortality and particulate matter also do not show evidence for a threshold concentration below which effects are not observed. If such a threshold level does exist it is likely to be at a very low level, below those measured in most urban areas of the world.

The available information indicates that the primary health impacts of concern are acute respiratory and cardiovascular health effects. Less information is available on the chronic health impacts of air pollution from vegetative fires. Indirect health impacts such as transportation accidents may also be associated with reduced visibility due to fire-related air pollution.

3.2.2 ACUTE HEALTH IMPACTS OF SMOKE FROM BIOMASS BURNING

The epidemiological studies of indoor and community exposure to biomass smoke indicate a consistent relationship between exposure and increased respiratory symptoms, increased risk of respiratory illness and decreased lung function. A limited number of studies also indicates an association between biomass smoke exposure and visits to Emergency Departments. This literature is reviewed in detail elsewhere (Larson and Koenig, 1994; Brauer, 1998). Recent assessments of impacts from the 1997-98 Southeast Asian haze episode support the association with increased hospital visits. Studies of the relationship between biomass smoke and mortality have not been conducted to date.

The 1997-98 Southeast Asian haze episode produced a large amount of information regarding acute health impacts within the general population. These are described in country reports presented during the 1998 WHO Bi-regional Workshop on the Health Effects of Haze-Related Air Pollution (WHO, 1998c). A summary of these reports are presented in Annex H. The country reports demonstrated that air pollution levels observed in South-East Asia in the 1997 and 1998 haze periods were significantly higher than generally accepted ambient air quality standards and guidelines. Particulate matter concentrations in the haze were substantially higher than those of gaseous air pollutants and urban aerosols. This indicates that the air pollutants of greatest concern came from the vegetation fires. Health impact studies showed that respiratory-related hospital visits increased in the most heavily impacted areas during peak haze periods; the frequency of attacks among selected asthmatic children in Malaysia also increased; and lung function among a study group of school children in Malaysia was decreased.

Besides the initial evaluation of health impacts associated with the 1997-98 Southeast Asian haze episode, only a very limited number of studies have evaluated community exposure to biomass smoke. Case studies describing smoke episodes and health risks for Indonesia (Dawud, 1998; Kunii, 1998), and Thailand (Phonboon, 1998) are presented in the Background Papers document. In a recent study (Long, et al. 1998), 428 subjects with moderate-to-severe airway obstruction were surveyed for their respiratory symptoms during a two-week exposure to combustion emissions from agricultural burning (straw and stubble). During the exposure period, 24-hour average PM_{10} levels increased from 15-40 $\mu g/m^3$ to 80-110 $\mu g/m^3$. Thirty-seven percent of the subjects were not bothered by smoke at all. Forty-two percent reported that symptoms developed (cough, wheezing, chest tightness, and shortness of breath), or became worse due to the air pollution. Twenty percent reported that they had breathing trouble. Those with symptoms were more likely to be female than male and were more likely to be ex-smokers than smokers. Subjects with asthma and chronic bronchitis were also more likely to be affected. The results of this study suggest that individuals with pre-existing respiratory diseases are particularly susceptible.

An analysis of the 1994 Singapore haze episode (Chew, et al. 1995) indicated an association between PM_{10} and increased Emergency Department visits for childhood asthma. During the haze period, mean PM_{10} levels were 20% higher than the annual average. Although a time series analysis was not conducted, the authors suggest that the association remained significant for all concentrations above 158 $\mu g/m^3$.

Two studies have been conducted regarding asthma Emergency Department visits and PM_{10} levels associated with smoke from bush fires in Sydney, Australia (Copper, et al. 1994; Smith, et al. 1996). During 1994, PM_{10} levels were elevated for a 7-day period (maximum hourly values of approximately 250 $\mu g/m^3$). Ozone levels were not elevated during the period in which smoke impacted Sydney. Neither study detected any increase in asthma Emergency Department visits during the bush-fire smoke episode.

A similar analysis evaluated the impact of a number of large forest fires in California on Emergency Department visits (Duclos, et al. 1990). During the approximately 2½-week period of the fires, asthma and chronic obstructive pulmonary disease visits increased by 40% and 30%, respectively. PM_{10} concentrations as high as 237 $\mu g/m^3$ were measured.

The health effects of biomass smoke inhalation have been documented in developing countries, where women spend many hours cooking over unventilated indoor stoves. In some cases children, and more often infants, are also exposed to inhalation of smoke from these sources. In developing countries, the potential health effects of exposure to biomass combustion emissions are widespread and have recently been reviewed (Smith 1993, Smith, 1996). Studies in developing countries indicate that biomass smoke exposure is associated with acute respiratory illness in children. As these exposures are much higher than the short-term exposures from forest fires, direct comparisons are difficult to make. These studies do indicate the serious consequences of exposure to high levels of biomass smoke. Increased acute respiratory illness in children associated with biomass smoke exposure is a likely cause of infant mortality and is also associated with substantial morbidity.

Wildland (forest) firefighters comprise an occupational group with high exposure to biomass smoke (Reinhardt and Ottmar 1997). The information on firefighters is presented here to suggest a plausible association between biomass smoke exposure and adverse health effects for the general population. Studies of wildland firefighters clearly indicate an association between exposure and acute effects on respiratory health (Rothman, et al. 1991; Liu, et al. 1992; Harrison, et al. 1995; Serra et al. 1996; Betchley et al. 1997). Cross-seasonal effects have also been observed in most studies, although these effects appear to be relatively small and may be reversible. It must be noted that firefighters are normally among the most physically fit in the entire population and do not normally suffer from any pre-existing health conditions. It is reasonable to argue that the demonstration of health impacts among firefighters provides strong evidence that similar effects will be observed within the general population at equivalent or lower levels of exposure. Exposures of this population are seasonal (4-5 months per year) and highly variable. Exposures depend upon the number of fires per season, their intensity and specific job tasks of fire fighters.

Residents of North American communities where wood burning is prevalent are another population with exposure to biomass pollution. Elevated levels of ambient air pollution caused by this practice are seasonal (3-8 months depending upon the climate) and variable, as they are strongly influenced by local meteorology. PM_{10} concentrations as high as 800 µg/m^3 have been measured in these communities, although peak levels (24-hour averages) of 200 – 400 µg/m^3 are more common. Nearly all of these studies found that pollution concentrations were much lower than those associated with the 1997 Southeast Asian haze episode. Similarly, studies of seasonal exposure to wood smoke, with exposures comparable to those experienced in Southeast Asia, found that it is reasonable to expect that vegetation fire episodes, such as the 1997 Southeast Asian episode, will result in the entire spectrum of acute impacts. These include increased mortality, sub-chronic (seasonal) effects on lung function and respiratory illness and symptoms. It is not possible at this time to determine the long-term effect, if any, from a single air pollution episode, although yearly occurrences of high biomass smoke exposure should be cause for concern. Chronic (several years) exposure to particle air pollution in urban areas, at much lower levels than experienced in Southeast Asia in 1997, has been associated with decreased life expectancy and with the development of new cases of chronic lung disease.

3.2.3 ACUTE HEALTH IMPACTS OF PARTICLE AIR POLLUTION

Numerous studies have indicated that current levels of particle air pollution are associated with adverse health outcomes. The most startling finding of these studies is the association of particle air pollution with increased daily mortality (Schwartz, 1991; Dockery et al.,1992; Pope et al., 1992; Schwartz and Dockery, 1992a; Schwartz and Dockery, 1992b; Dockery et al., 1993;

Schwartz, 1993; Spix et al., 1993; Pope et al., 1995). One common feature of the studies is that the ambient particulate matter is produced in combustion processes. Studies of naturally produced particles (such as those generated from windblown soil or volcanic eruptions) show a much smaller impact on health, for an equivalent particle concentration (Hefflin et al., 1994; Buist et al., 1983; Dockery and Pope, 1994). In nearly all cases, the studies indicate an association between particle air pollution and increased risk of death, primarily in the elderly and in individuals with pre-existing respiratory and/or cardiac illness (Schwartz 1994a; Schwartz 1994b). Recent studies have also suggested an association between particles and infant mortality (Bobak and Leon, 1992; Woodruff et al., 1997), as well as with low birth weight (Wang et al. 1997). Increased risk of hospital admissions and increased Emergency Department visits have also been associated with short-term increases in the levels of particle air pollution (Pope, 1989; Pope, 1991; Schwartz et al., 1993; Dockery and Pope, 1994; Schwartz, 1994a; Schwartz, 1994b; Schwartz, 1995; Schwartz, 1996).

The WHO Air Quality Guidelines for Europe declined to recommend specific guideline values for particulate matter, as the available studies do not indicate an obvious exposure concentration and duration that could be judged a threshold (WHO, 1995). Instead, the available data suggest a continuum of effects with increasing exposure. Table 3.2.3-1, constructed in part from the WHO Guidelines, summarizes the quantitative relationships between the concentrations of ambient air particles and various health outcomes.

TABLE 3.2.3-1 95% confidence intervals and arithmetic means of percent changes in mortality and morbidity due to PM_{10}, estimated per 10 $\mu g/m^3$ (WHO, 1995; Dockery and Pope, 1994).

Effect	% change
Increase in daily mortality	
Total deaths	0.59-0.82
Respiratory deaths	3.4
Cardiovascular deaths	1.4
Increase in hospital usage (all respiratory)	
Admissions	0.50-1.17
Emergency department visits	1.0
Exacerbation of asthma	
Asthmatic attacks	3.0
Bronchodilator	2.05-4.70
Emergency department visits*	3.4
Hospital admissions	1.9
Increase in respiratory symptom reports	
Lower respiratory	1.84-5.08
Upper respiratory	0.7
Cough	2.27-6.87
Decrease in lung function	
Forced expiratory volume	0.15
Peak expiratory flow	0.08

An illustration of how to apply the WHO guidelines to estimate mortality rates in Indonesia is illustrated below:

Expected number of deaths = r/(1+r) x (current mortality rate) x (exposed population)

where r is the additional risk associated with the current level of particles, relative to a reference level. r is calculated by:

r = (estimated percent effect of PM_{10} per ug/m^3) x (1/100) x (change in PM_{10})

To calculate r, we use the following inputs: 565 $\mu g/m^3$ as the one-month average concentration of PM_{10}, and 143 $\mu g/m^3$ as the ambient PM_{10} concentration (i.e. 565 - 143 = 422 $\mu g/m^3$ for the change in PM_{10}). The estimated effect of PM_{10} is 0.0705%/$\mu g/m^3$. Then r is:

r = (0.0705 x (1/100) x 422) = 0.30,

From this value of r, and 7.5 per 1000 as an estimate of the current mortality rate (derived from the period 1990-1995 in Indonesia) and 12 million for the exposed population,
the number of expected deaths is:

Expected number of deaths = 0.30/1.30 x (7.5/1000) x 12,000,000 = 20,769.

3.2.4 CHRONIC HEALTH IMPACTS OF SMOKE FROM BIOMASS BURNING

Lung disease

The health effects of biomass smoke inhalation have been documented in developing countries where women spend many hours cooking over non-vented indoor stoves. These studies indicate that biomass smoke exposure is associated with the development of chronic lung disease in adults (Sandoval et al. 1993; Dennis et al. 1996; Perez-Padilla et al. 1996). As these exposures are much higher than would occur as a result of short-term exposure to biomass smoke from vegetation fires, direct comparisons are difficult to make. These studies indicate the serious consequences of exposure to high levels of biomass smoke. In particular, the development of chronic lung disease in adults is associated with premature mortality and substantial morbidity.

Cancer

Studies consistently suggest that ambient air pollution resulting from fossil fuel combustion is associated with increased rates of lung cancer. Two recent prospective cohort studies observed 30-50% increases in lung cancer rates associated with exposure to respirable particles, best viewed as a complex mixture originating from diesel exhaust, coal, gasoline and wood burning. The excess lung cancer risk associated with ambient air pollution (relative risks of 1.0 – 1.6) is small compared with that from cigarette smoking (relative risks of 7 – 22). It is, however, comparable to the risk associated with long-term exposure to environmental tobacco smoke (relative risk of 1.0 – 1.5) (Cohen and Pope 1995; Cohen et al. 1997).

The limited data on biomass smoke and cancer do not indicate an increased risk, even at very high levels of exposure. This evidence includes studies of long-term exposure to high levels of biomass smoke from domestic cooking in developing countries. Evidence for a relationship between urban particle air pollution and lung cancer is also limited, but suggests a small increased risk. There have not been enough studies conducted to evaluate the consistency of any increased risk for different particle sources. However, while biomass smoke clearly is potentially carcinogenic, it is much less so than motor vehicle exhaust (Lewis et al. 1988; Lewtas et al 1992; Cupitt et al. 1994).

3.3 PUBLIC ADVISORIES

3.3.1 INFORMATION TO THE PUBLIC

Among the critical components of national governments' efforts to manage vegetation fire episodes are the education of the population regarding the potential health impacts of air pollution produced in vegetation fires. These education efforts must occur prior to the occurrence of an episode and also during episode periods to keep the population informed. The major components of such an information programme include air quality monitoring; a system to periodically collect information on pollution-related illnesses for purposes of surveillance; the communication of a national action plan (including information on health impacts and mitigation measures); operation procedures for action plans; special educational efforts directed towards susceptible population sub-groups; and preparation in the ability to respond to frequently asked questions.

3.3.2 INFORMATION ON AMBIENT AIR QUALITY

Among the basic requirements for protecting public health during vegetation fire emergencies is the provision of a reliable air quality monitoring and management system. Information on ambient air quality is of prime importance, as it is the basis of preventive and protective action that needs to be taken by the population to minimize damage to health. An air quality monitoring programme should be a primary activity for protecting the public against air pollution episodes, such as vegetation fires. In general, the air quality monitoring programme could have the following objectives:

- to assess the nature and magnitude of air pollution problems
- to monitor trends in the ambient air quality, so as to enable decisions to prevent air pollution episodes
- to assess the effectiveness of pollution control measures implemented to improve ambient air quality

This establishment of a well-managed air quality monitoring infrastructure and programme would be the first step in building a health information system for the public. In the event that actual onsite air monitoring data cannot be obtained, estimates of smoke concentrations may have to be based on visibility observations, but their correlation with particle concentrations in the local context need to be validated. An example of such a relationship is shown in table 3.3.2-1:

Table 3.3.2-1 Approximate Relationship between Wildfire Smoke Concentrations and Visibility Conditions

Pollutant Standard Index (PSI)	PM_{10} Particulate Matter [$\mu g/m^3$]	Visibility, [km]/[miles]
100	150	6.0/3.7
200	350	3.0/1.8
400	500	1.5/0.9
500	600	1.0/0.6
>500	800	0.7/0.4

Once an air quality monitoring and management system is in place, authorities must decide on the air quality standards and goals to be set for the population. The standards and goals set by other countries or international agencies, that have carried out credible research on air quality and health impact, could be adopted. For example, the 24-hour Pollutant Standards Index (PSI) developed by the USEPA (indicated above for PM_{10}) is useful as it is accepted internationally and is based on evidence of population health effects due to various air pollutant components (USEPA, 1994).

It should be noted that in the event of an emergency due to vegetation fires, the health alert advisory given for the previous 24-hour pollution levels (indicated by PSI levels) may not be adequate to help the population react quickly and modify their activities. Pollution indices should not be overemphasized. It is also important to report pollutant-specific information. This applies particularly to PM_{10} as the research community, and WHO air quality guidelines generally, do not support the concept of a threshold (or no-adverse effect) level for particle exposure. Index readings slightly below "unhealthy" levels, when based on PM_{10} measurements, may provide a false sense of security. In fact, there will probably be recognizable health impacts at these levels. Modifications to the air quality reporting system may need to be made by the government, to ensure more timely information on the pollution levels during serious emergencies. Information on pollution levels should be made through the broadcasting media, together with appropriate health advisories.

3.3.3 INFORMATION ON NATIONAL ACTION

A comprehensive National Haze Action Plan (NHAP) should be developed to ensure that the population is fully prepared in the event of vegetation fire pollution. This will mitigate the impact of haze on the health and well being of the general public. This is particularly important for the more vulnerable sections of the population, such as asthmatics, the elderly and children. Based on the NHAP, government departments should draw up operating procedures to be adopted in the event of a vegetation fire pollution emergency. These procedures should be widely publicized through the media, before the occurrence of any vegetation fire pollution. This will ensure that the population knows the changes that would be made to public services and facilities, and familiarize them with the modifications in their activities that are necessary to reduce the health effects of pollution.

3.3.4 INFORMATION ON HEALTH EFFECTS AND CAUTIONARY STATEMENTS

It is imperative that authorities monitor the population's health during a fire pollution emergency to detect any worsening of the impact at different pollution levels. Data on haze-related illnesses from primary health care providers, hospitals, and mortality registries should be reported periodically. Monitoring the impact of pollution requires that baseline data are available for comparison. In the longer term, the information gathered would enable authorities to refine their national action plan.

Special emphasis should be placed on explaining the health effects of susceptible populations such as asthmatics, the elderly and children at different pollution levels. This will help ensure there are adequate preparations to deal with the expected increase in demand for medical services from the susceptible population during fire pollution episodes.

Frequently asked questions, such as concern about the safety of food and potable water, should be addressed by authorities through the media. Based on available medical literature, there is no conclusive evidence to indicate that adverse health effects result from the consumption of exposed food or water.

3.3.5 RECOMMENDATIONS

- ☐ An air quality monitoring programme should be a primary activity to protect the public against air pollution associated with smoke haze.
- ☐ To ensure full preparedness of the population for the health impacts of vegetation fire pollution, a comprehensive National Haze Action Plan should be developed and widely publicized through the media before any air pollution episode.
- ☐ Based on the National Haze Action Plan, government departments should develop operating procedures and ensure that the population will be aware of any changes made to public services and facilities in an emergency situation.
- ☐ Data on air pollution-related illnesses from primary health care providers, hospitals, and mortality registries should be reported periodically.
- ☐ Special educational efforts should be developed for susceptible populations such as asthmatics, the elderly, and children to ensure that they are adequately prepared to deal with air pollution episodes.
- ☐ Health authorities, via the media, should proactively address frequently asked questions (such as the safety of food and potable water supplies exposed to smoke for prolonged periods).

3.4 MITIGATION MEASURES

Mitigation measures recommended for acute events are listed, beginning with the simplest measures and progressing to those that may cause greater disruption and have greater technological and/or financial requirements.

3.4.1 REMAINING INDOORS

For non-air-conditioned homes or buildings, only limited protection from fine particle air pollution is gained by remaining indoors. Recent research has indicated that the impact of outdoor particles on indoor levels is determined mainly by the rate of ventilation, and that the impact of outdoor particles can easily be calculated for any air exchange rate. In typical North American homes, outdoor air accounts for 75% and 65% of fine and coarse particles, respectively. The geometric mean air exchange rates are 0.45-0.55/h, but vary by season and specific geographic location. In general, air conditioned homes typically have lower air exchange rates than homes that use open windows for ventilation. In one study, air conditioned homes had air exchange rates of 0.8/h, while non air-conditioned homes had rates of 1.2/h, implying indoor fractions of outdoor $PM_{2.5}$ of 67% and 75%, respectively. One method of reducing particle exposure would be to decrease air exchange rates. This could be accomplished by insulating for cold seasons and installing air conditioners for hot seasons to reduce the use of open windows. The infiltration of outdoor particles into commercial buildings is likely to be highly variable, as it is dependent upon the air exchange rate and specific characteristics of the ventilation system, including the efficiency of air filters.

To enhance the protection offered by remaining indoors, individuals/building managers should take action to reduce the infiltration of outdoor air. Air conditioners, especially those with efficient filters, will substantially reduce indoor particle levels. Schools, childcare centres, retirement centres, nursing homes, hospitals, and hospices especially should be urged to provide air-conditioned rooms to susceptible individuals. To the extent possible, effective filters should be installed and maintained in existing air conditioning systems and individuals should seek environments protected by such systems.

3.4.2 PERSONAL LIFESTYLE MODIFICATIONS

In addition to remaining indoors, the authorities should advise members of the public on other mitigation measures involving personal lifestyle modifications, such as the reduction of physical activity and restriction of cigarette smoking.

3.4.3 USE OF AIR CLEANERS

Air cleaners can be used as a mitigation measure against pollution due to vegetation fires. Information on their effectiveness should be publicized. Portable air cleaners are compact, stand-alone appliances designed to lower the particle levels of an enclosed space. Air cleaners are able to reduce the level of fine particles in a typical living room or bedroom to an acceptable level when there is intense haze, for example when the PSI reading exceeds 200. Air cleaners are classified by their Clean Air Delivery Rate (CADR) which describes the volume of air the cleaner can filter. By matching a device's CADR to the space in which it is placed, effective air cleaning can be achieved. Recommendations should be made on the use of air cleaners, particularly to households with members who are vulnerable to the effects of deterioration in air quality. Evaluation could be conducted on models of air cleaners available in the market (or a certification programme could be established) and appropriate recommendations be made to the public, to assist them in purchasing the model suitable for their homes or offices. Unfortunately, economics will limit the distribution of such devices throughout the population. As with air conditioners, the increased use of air cleaners by a large segment of the population may have a significant impact on energy consumption.

3.4.4 USE OF MASKS

The public should be advised on the use of masks, particularly when they are involved in outdoor activities during periods of air pollution. The public should also be informed on the selection of mask types from those available and their relative utility in keeping out particles from the smoke haze. While makeshift masks (e.g., handkerchiefs) are inexpensive and may be used by a large segment of the population, their effectiveness must be questioned. Despite this reservation, it is likely that the benefits of wearing these masks will outweigh the physiological and economic costs.

Basically, there are two categories of masks in the market: surgical (or similar) masks and respirators. The public should be advised that surgical masks are not very useful in preventing the inhalation of fine particle emission from vegetation fires. These masks generally cannot filter out particles less than 10 μm in size. Respirators, on the other hand, are special masks designed for the protection of workers exposed to occupational health hazards. Typically these respirators can filter out 95% or more of fine particles produced during vegetation fire episodes.

While respirators may be useful, they are uncomfortable and increase the effort of breathing. Respirators may have a role for those with chronic cardio-respiratory illness, but they should be used on the recommendation of attending doctors. According to some assessments, over an eight-hour period of use, a respirator of 95% efficiency can offer satisfactory filtration for an average healthy adult without undue breathing resistance. At higher efficiencies, breathing resistance increases and the user will experience more discomfort.

During intense haze, the public should avoid outdoor activity, rather than put on a mask and stay outdoors for prolonged periods. However, for those who cannot avoid going outdoors, the use of respirators would provide some relief. In the case of those with cardiopulmonary illness who need to use masks on the recommendation of their doctors, they should choose the right respirators, i.e., those designed for particles removal.

Classification and Description of Respirators by Mode of Operation

- Air-Purifying Respirators

  Ambient air, prior to being inhaled, is passed through a filter, cartridge, or canister, which removes particles, vapors, gases, or a combination of these contaminants. The breathing action of the wearer operates the non-powered type of respirator.

- Air-Supplying Respirators

  Clean air, independent of the ambient air condition, is supplied to the wearer.

  - Self-Contained Breathing Apparatus (SCBA). The wearer carries a supply of air, oxygen, or oxygen-generating material;

  - Supplied-Air Respirators;

  - Hose Mask: Equipped with a face piece, breathing tube, rugged safety harness, and large-diameter heavy-duty non-kinking air-supply hose.

Respirator Selection

In the selection of respirators it is important to understand the risk to individuals. Factors to be considered include emissions, concentration of oxygen, length of exposure, and physical activity. It may be necessary to consider the use of face pieces with cartridges, full face pieces or SCBAs. In the USA, the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have defined standards that regulate the use and certification of respirators (NIOSH, 1995; OSHA, 1998b). Under these regulations (42 CFR Part 84) NIOSH, for example, will certify three classes of filters (N, R, and P), with three levels of efficiency (95, 99, and 99.97%) in each class. The efficiency indicates the degree to which the filter removes small (0.3 μm) particles. N series (Not resistant to oil) respirators protect against particles that are free of oil or other severely degrading aerosols. These respirators have no time limitations, except for particle clogging, and are suitable for vegetation fire smoke.

In Europe, the European Committee for Standardization (CEN) also has standards for respiratory protection and classification (CEN, 1999). For particles, there are 3 types of filter efficiency levels: P1 (80%), P2 (94%) and P3 (99.97%). P1 respirators would be suitable for protecting the population from vegetation fire smoke.

The selection of a NIOSH- or CEN-approved respirator would depend on the availability within the specific region or country. There are also other agencies that approve respirators in different countries and their selection will depend on the local current standards. Table 3.4.4-1 provides guidance for the general public in the selection of respirators.

Table 3.4.4-1 Approximate Relationship between Wildfire Smoke Concentrations, General Health Effects, and Suggested Respirators

PM_{10} Particulate Matter [$\mu g/m^3$]	General Health Effects	Suggested Respirator
150	Mild aggravation of symptoms	None
350	Significant aggravation of symptoms and decreased exercise tolerance in susceptible groups	N95 or P1 for susceptible individuals involved in outside activities
500	Premature onset of certain diseases, significant aggravation of symptoms, and decrease exercise tolerance in healthy persons	N95 or P1 for healthy people involved in outside activities
600	Premature death in the ill and elderly. Healthy people will experience adverse symptoms that affect their activity.	N95 or P1 for susceptible people in indoor facilities without atmospheric controls.
800	Acute and incapacitating symptoms experienced by significant portions of population	N95 or P1 for healthy persons in indoor facilities without atmospheric controls.

3.4.5 OUTDOOR PRECAUTIONARY MEASURES

Precautionary measures should be taken to safeguard the health and safety of workers who must continue to perform outdoor work. Employers should provide suitable respirators to workers who need them for outdoor work, as part of the safety and health requirements for the protection of the health of their workers. Those who have difficulty using respirators and working outdoors should be deployed to do indoor work. In addition, outdoor work involving strenuous physical activity should be minimized. Outdoor work with a risk of falling from heights should not be allowed, unless precautions have been taken to reduce this risk.

Workers with existing heart or respiratory ailments are more susceptible to the effects of the haze. They should be advised to consult their doctors on their fitness to work outdoors and to use respirators. If they experience difficulty working outdoors, employers should deploy them to indoor work, which is less physically strenuous.

3.4.6 EVACUATION TO EMERGENCY SHELTERS

In severe episodes, another protection strategy is the preparation of emergency shelters with effective air conditioning and particle filtration. Susceptible individuals who do not have access to other air-conditioned environments should be allowed free access to emergency shelters. These could be located inside large commercial buildings, educational facilities or shopping malls. However, the risk of infection from over-crowding within these premises has also to be considered.

The emergency evacuation of whole populations to other geographical locations in response to smoke haze is not recommended as a mitigation measure.

3.4.7 SCHOOLS AND BUSINESS ACTIVITIES

The decision to close or curtail business activities will depend upon consideration of traffic, health, environmental, socioeconomic factors and other local conditions. Depending upon building designs, exposure inside schools are likely to be similar to those in homes or businesses. However, visibility could be so low during severe episodes that the risk of traffic accidents could also be increased. Further, restrictions on industrial emissions may be warranted, depending upon the local air pollution and the emission characteristics of particular industries.

3.4.8 RECOMMENDATIONS

- To enhance the protection offered by remaining indoors, individuals/building managers should take actions to reduce the infiltration of outdoor air.
- Schools, childcare centres, retirement centres, nursing homes, hospitals and hospices should especially be urged to provide air conditioned rooms to susceptible individuals, and effective filters should be installed and maintained in these rooms.
- During severe smoke episodes, members of the public should be advised on lifestyle modifications, such as the reduction of physical activities and the restriction of cigarette smoking.
- Evaluation of the use of portable air cleaners should be conducted and appropriate advice given to the public, to assist them in purchasing models suitable for homes or offices.
- Advice should be given to the public on specific respirator types and their relative utility for filtration of smoke particles. This includes the use and selection of appropriate dust masks/respirators available in the market.
- Precautionary measures, such as providing suitable respirators, should be taken to safeguard the health and safety of workers who must continue to perform outdoor work.
- In severe episodes, susceptible individuals should be allowed free access to air-conditioned emergency shelters (with adequate particle filtration). These could be located inside large commercial buildings, educational facilities or shopping malls.

3.5 GUIDANCE ON METHODOLOGY FOR ASSESSMENT OF VEGETATION FIRE-INDUCED HEALTH EFFECTS

3.5.1 BACKGROUND

Several factors are critical in ascertaining the health effects of air pollution exposure. These factors include: characteristics of the pollutants, population exposures, individual exposures, susceptibility of the exposed individual, potential confounding factors, and the range of health effects being studied. The availability of data on these factors greatly affects the type of study that might be undertaken.

Study designs in air pollution epidemiology vary widely and include: short-term controlled exposure studies (chamber studies); short-term exposure studies; and long-term exposure studies. This section will focus on the latter two study designs, as they reflect a typical epidemiological approach to the problem of air pollution exposure. During an emergency, however, it may be necessary to determine immediate needs in a community exposed to smoke from vegetation fires. In this situation, health authorities could conduct a rapid epidemiological assessment focusing on the demographics and health concerns of people in the affected community.

An important component of a public health plan to deal with pollution-related exposures is a surveillance system, which monitors respiratory or cardiovascular diseases. While many countries have such a system in place for infectious diseases, very few have a similar system in place for noninfectious diseases. With the increasing numbers of computerized clinical databases, however, it may be possible to set up a surveillance system for diseases that would be affected by fire-related air pollutants.

3.5.2 IMPORTANT POTENTIAL FACTORS FOR ALL STUDIES

Given the objective of protecting the public health, a complete understanding of the spectrum of health effects from vegetation fires requires knowledge of the full range and potential of factors that might affect health or have related impacts. Although total emissions and adverse health effects have been documented for particulate matter, information on other factors that potentially affect human health is lacking. Nevertheless, these other factors should be considered when evaluating the effects of any vegetation fire, particularly in developing countries. Additional factors may present themselves in future fire episodes. Important factors include:

- Community air pollution measurements.

  Having population based monitors (as opposed to source based monitors) is important for obtaining better information on population exposures.

  - Particulate matter (PM_{10}, $PM_{2.5}$)

    The current trend is to obtain more data on the finer particle fraction. Coarser fractions can contain dust from windblown earth or sand, which can affect visibility, but which has only a small effect on human health. The fine particle fraction is probably the best indicator of transported fire smoke.

  - Carbon monoxide and Ozone

    Carbon monoxide is an indicator of incomplete combustion and may be a useful surrogate measure for smoke exposure. Ozone levels may increase in association with a vegetation fire, but these levels are minimally increased compared to particle pollution levels. Ozone level measurement should not be part of a public health response to a vegetation fire emergency.

  - Volatile Organic Compounds (VOCs).

    VOCs may serve as markers for fire-related pollutant exposure. However, these are useful only as a research tool, and VOC measurements should not be part of a public health response to a vegetation fire emergency.

- Data on personal exposure to pollutants (these types of data are less likely to be available).

  - Personal or home based air sampling.

    While this type of sampling gives the best and most valuable data, it is impractical in large studies. Some studies have used personal monitors to validate the use of population based monitors.

  - Biomarkers of exposure.

    If an appropriate VOC was identified it might be possible to obtain blood samples and analyze them for this compound as a marker of recent exposure.

  - Non-pollutant environmental factors associated with air quality and health outcomes.

    Most of the health outcomes that are studied (respiratory disease exacerbation or hospitalization) are affected by weather changes. Weather changes can also affect air pollution due to factors such as inversions and wind speed. Important quantities to be considered include temperature, wind speed and direction, humidity, seasonality, and occurrence of pollen and other allergens.

- Factors affecting personal exposure to outdoor air pollutants.

  The following factors should also be considered in any epidemiological study:

  - Time activity patterns.

    In the most developed countries and in many developing countries more than 90% of time is spent in indoor environments. This proportion may vary somewhat throughout the world.

    - Housing characteristics.

      People who occupy structures that permit air exchange (e.g., open windows) with the outside environment may experience a greater susceptibility to respiratory illness than those in sealed structures. In many tropical regions there is not a true “indoor” environment.

    - Interventions to reduce pollutant exposures.

      Although these interventions have been recommended, their efficacy is still unclear.

    - Masks or respirators - these typically increase the work of breathing.
    - Going indoors.

- Factors affecting personal outcomes and pollutant exposure.
    - Age, ethnicity, and gender.

      Young children and the elderly are generally at greater risk for cardiopulmonary morbidity and mortality.

    - Pre-existing diseases.

      People with pre-existing respiratory disease (asthma and chronic obstructive pulmonary disease) or heart disease are usually more susceptible to air pollutants.

    - Pregnancy.
    - Socioeconomic status.

      Socioeconomic status can affect both exposure to pollutants (because of location or type of housing) and health outcomes (due to access to care and treatment). People with greater access to resources and services would have the means to take protective measures against fire-related emissions, such as air cleaners, filters, and air conditioners.

    - Occupational exposures.

      Some occupational exposures are associated with chronic respiratory diseases. Outdoor workers are at higher risk for respiratory illness than indoor workers. The total exposure due to ambient, indoor and occupational air pollution might be substantially different from ambient exposure.

    - Tobacco Smoking.

Tobacco smoking is a well-known cause of respiratory and pulmonary diseases, including lung cancer. Tobacco smokers are at higher risk for other chronic respiratory health effects than are non-smokers. These effects may be exacerbated under conditions of increased airborne emissions.

- Nutritional status

  A low nutritional status may increase an individual's susceptibility to air pollution.

- Cooking practices.

  Women in developing countries, in particular, are at risk for respiratory illnesses when cooking with open fires inside the home.

- Access to information, health care, and potable water.

  People with access to the media may be alerted to episodes of smoke or haze, and obtain educational information for responding to those episodes. Persons with access to health care have a greater survivability for disease than those for whom access is limited. Access to potable water when a drought occurs concurrently with fires indicates a favorable health status.

- Health Outcomes.

The type of health outcome studied depends on the types of data available and the type of analysis planned.

- Mortality.

  Usually data are available on mortality, although the quality of cause-specific data can vary in different parts of the world.

- Total Cardiopulmonary Hospitalizations.

  Information on this is frequently available using administrative or billing data. It also can be available from the hospital directly, but may require manual searches.

- Emergency Department or outpatient visits.

  Information is sometimes available using administrative data. Many studies have used Emergency Department logbooks to extract data.

- Symptomatic exacerbation.

  This component of panel or cohort studies can be linked to Emergency Department visits or hospitalizations.

- Changes in lung function.

This quantity is part of a panel study and requires the use of peak flow or portable spirometry measurement. It can also be part of an exposed/unexposed study.

- Cardiopulmonary symptoms.

  This variable is also part of a panel study, an exposed/unexposed study or cross sectional survey. Typical symptoms include cough, wheezing, shortness of breath, and angina

- Upper respiratory illnesses.

  This variable is also part of a panel study, an exposed/unexposed study or cross sectional survey.

- Mucous Membrane Irritation.

  This variable is part of a panel study or cross sectional survey. Includes conjunctivitis and ear, nose or throat irritation.

3.5.3 STUDY DESIGNS TO DETECT HEALTH EFFECTS RELATED TO ACUTE EXPOSURES

Health effects can include death, hospitalization, exacerbation of diseases, worsening of pre-existing diseases, worsening of symptoms, and worsening of physiological parameters such as lung function.

- Population based studies.

  These study models typically focus on endpoints, such as mortality or hospitalization for either specific diseases or all diseases. The prototype in this category is the study of deaths in the London smog episode of 1952.

- Time series studies.

  In recent years numerous time series studies have been published that focused on the effect of particle air pollution on mortality due to cardiovascular and respiratory diseases, and on hospitalization due to diseases such as asthma, pneumonia, Chronic obstructive pulmonary disease (COPD), coronary artery disease and congestive heart failure. These types of studies can be very complicated analytically.

- Cohort or individual based studies.

  These studies typically focus on endpoints such as symptoms or exacerbation of disease, or worsening of lung function.

- Panel studies.

Panel studies measure data (peak flows, use of bronchodilators, asthma symptoms, personal monitoring) in a small group of people (e.g. people with asthma) over a relatively short period of time. Such studies typically depend on self-reporting and may present analytic challenges.

- Case-control studies.

  In case-control studies individuals are sampled with a specific acute health endpoint, such as an exacerbation of lung disease, or death from cardiopulmonary disease, and compared to similar individuals without these endpoints. Previous exposures to pollutants and other risk factors are also assessed. Limitations include problems in assessing retrospective exposures. This type of study might be a useful model for examining the effects of preventive interventions.

3.5.4 STUDY DESIGNS TO DETECT EFFECTS RELATED TO CHRONIC EXPOSURES

Health effects due to chronic exposure to air pollutants can include mortality, hospitalization rates, disease rates (such as COPD, heart disease and lung cancer), and lower levels of lung function. In contrast, studies related to episodic vegetation fire exposure focus on acute health effects. Thus, any studies looking at chronic exposures and chronic health effects should be part of a research project and not part of a public health response to an emergency situation.

- Population based ecological studies.

  In these studies the specific exposure of an individual is not known, but the community exposures are. The goal in these types of studies is to look at outcomes (long term mortality rates or disease rates) in areas with large differences in air pollution levels. Important issues in this type of studies are the consideration of confounding factors and the quality assurance of data.

- Cohort studies.

  These studies follow groups of subjects on whom baseline data (sex, age, smoking status, occupation, presence of underlying disease, etc.) is collected. These groups are followed over time to look for outcomes such as early mortality, development of cardiopulmonary disease, or declines in lung function. While these studies have the potential to yield very important data in a well-defined population, they are limited in being very costly and difficult to perform.

- Case-control study.

  These studies sample individuals with a specific chronic health endpoint (such as development of COPD, lung cancer or congestive heart failure) and similar individuals without these endpoints. Previous exposures of the individuals to pollutants and other risk factors are then assessed. Limitations of this kind of study include problems with assessing retrospective exposures.

3.5.5 EVALUATION OF STUDY DATA

Data collected in any of these studies need to be analyzed carefully, accounting for the appropriate confounding factors and co-variates. Techniques of analytical statistics vary with the type of study design used, and are well beyond the scope of this document. New statistical routines have been developed, to better determine important factors in health effects related to pollutant exposures.

3.5.6 PRIORITIES

The priorities of a research plan to evaluate health effects depend on the type of resources and data available, and on the knowledge that is hoped to be gained from the research. It is unlikely that research could actually guide decision-makers during the course of an emergency, except in an instance where active surveillance for cardio-respiratory diseases was ongoing and provided data in real time. While prospective studies are valuable and provide important information, they depend on consistent or predictable exposures occurring in the population being studied. Vegetation fires are by nature episodic, and their health impacts may not be easy to assess using prospective study designs. For research that occurs after the vegetation-fires, retrospective analyses of existing data would probably provide the most useful data to decision makers.

3.5.7 CONCLUSIONS

Determining the health effects related to vegetation fires is a difficult task. There are a variety of different study models that can be used, depending on the resources and data available. Any model, though, requires careful planning of the design, implementation and analysis of the study.

Before a fire emergency a health department could set up a surveillance system to detect chronic cardio-respiratory diseases. If this was in place, changes in these diseases could be monitored during a fire episode. In the absence of such a surveillance system, it is unlikely that any active surveillance would provide reliable information that a public health department could act on. After a fire episode, several research designs are available to health departments for determining the health effects of the fire episode, and the data can be used to shape future policy.

3.6 APPLICATION OF APPROPRIATE SHORT-TERM AIR QUALITY GUIDELINES

3.6.1 INTRODUCTION

The primary purpose of these guidelines is to protect public health from the impacts of smoke from vegetation fires. Air quality guidelines provide exposure levels that do not constitute a significant health risk and are usually based on the latest scientific knowledge. Ecological concerns may be included as well. For the derivation of air quality standards, national and local authorities need to take other factors into account when making risk assessment and risk management decisions. These include prevailing exposure levels, technical feasibility, source control measures, abatement strategies, as well as social, economic, and cultural conditions (WHO 1987).

3.6.2 DUAL ROLE OF SHORT-TERM AIR QUALITY GUIDELINES AS A TOOL IN RISK MANAGEMENT

During short-term air quality deterioration, such as during a vegetation fire, there is a need for immediate action to mitigate adverse health impacts of the public. In this situation, air quality guidelines should also serve as a public information tool to guide recommended action. These guidelines should link air quality and/or exposure levels with public cautionary measures and health-risk communication activities (described under section 3.3). Different levels of exposure, health effects, and measures should be established for field operations (e.g. mild, moderate, severe), with consideration of the non-health factors referred to earlier. This approach is illustrated with two examples of guidelines adopted in Europe and the U.S.A.

First, in a number of countries in Europe, an “air pollution alert system” is used a guide for measures to be undertaken when peak exposures to urban winter- or summer-type smog occur (WHO 1992). In general, when effects are expected to be mild, no action other than an announcement of the expected alert and its public health significance seems necessary. When effects are expected to be moderate, some public advice about exposure or dose reduction for sensitive individuals could be considered. When severe health effects are expected, additional measures can be recommended on a voluntary basis, and emergency short-term measures such as closing of schools or limiting traffic can be considered.

Second, USEPA and several agencies developed the PSI, an urban air quality composite index, based on integrated ambient measures of criteria pollutants (USEPA, 1994). USEPA and local officials use the PSI as a public information tool, to advise the public about the general health effects associated with different pollution levels, and to describe whatever precautionary steps may need to be taken. Similar to the European example, a slight increase of the index or particulate matter will trigger health advisories by state and local officials. The next level will trigger an “Alert” stage when the pollution level might cause some activities to be restricted. A level above that will trigger a “Warning” stage, which is likely to prohibit some pollution causing activities. The next level above that would be an “Emergency” and would require cessation of most pollution causing activities.

3.6.3 APPLICABILITY OF WHO AIR QUALITY GUIDELINES

Smoke from vegetation fires consists of fine particles in the respirable range. These particles are subjected to long-range and transboundary transport, resulting in widespread short-term increases in the levels of particulate matter throughout affected areas. Particulate matter requires special consideration in making appropriate short-term air quality guidelines. New epidemiological data failed to identify a threshold particle exposure level, below which no effects would be expected (Wilson and Spengler 1996, WHO 1999). Instead of the usual threshold values, national and local authorities are now guided by the relationships between particle exposures and health impacts to set up their own levels. This risk assessment approach assumes that there are health impacts at all exposure levels and policies need to be developed to minimize the risk of the various impacts.

For practical purposes, air quality guidelines can be developed for short-term vegetation fires, using the same general approach of the WHO guidelines (WHO 1987, 1999), in combination with the risk management approach described above. There may be questions regarding both the averaging time and the measurements that best represent air quality or exposure levels. A 24-hour averaging time would conform to the available evidence on the short-term effects of daily exposure in time-series studies. As fine particulate matter is the main pollutant of concern with vegetation fires, the measurement of particle concentrations should be used in the vegetation-fire guidelines, to directly reflect their health effects.

In practice, national and local officials may decide to establish few levels of particulate matter (PM_{10} or $PM_{2.5}$) that relate to the corresponding health effects and public advisory and mitigating activities (Sections 3.3, 3.4). For example, three levels above the normal background such as mild (alert), moderate (warning), and severe (emergency) stages may be developed. The available exposure-response information in the WHO air quality guidelines will form the basis for building intervals appropriate for individual countries or locations. The idea of these short-term air quality guidelines for smoke from vegetation fires is illustrated in Figure 3.6.3-1.

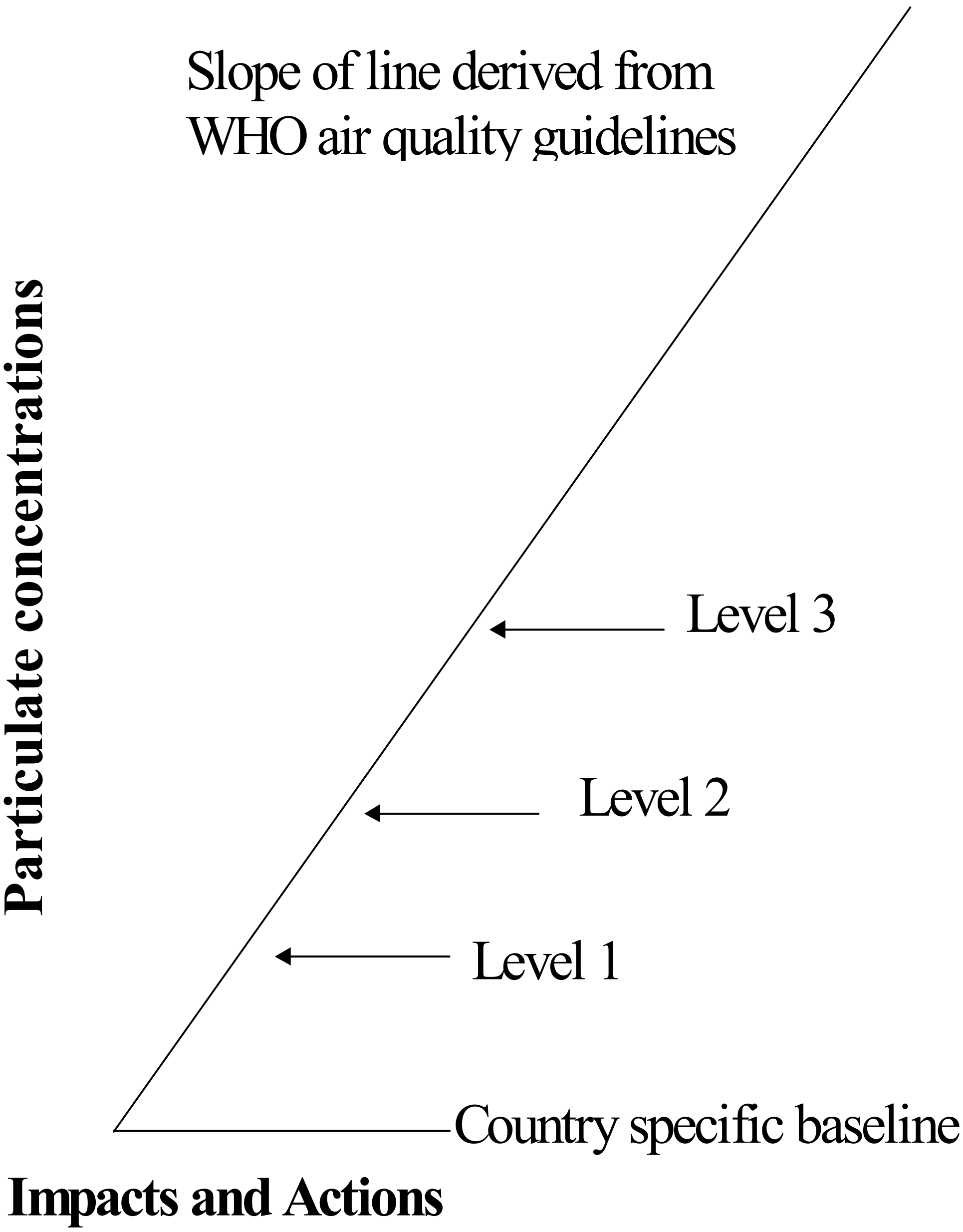

Figure 3.6.3-1 Various levels of alert systems

Proposed Advisory Stages

Each of the following action plans suggests that individuals remain indoors to reduce their exposure to smoke. In poorly sealed, drafty homes with a high air exchange rate, this recommendation may offer little protection from smoke exposure.

Level 1, Alert

Action: All individuals with pre-existing lung or heart disease should try to remain indoors, with doors and windows closed, and should avoid excessive exertion and exposure to tobacco smoke and other respiratory irritants. People who need to take regular medications should make sure that they have at least a five-day supply. Individuals with chronic medical conditions should contact their physicians for guidance, regardless of the occurrence of symptoms. All others should contact a health care provider in the event of any of the following symptoms: headache, repeated coughing, chest tightness or pain, wheezing, excessive phlegm, difficulty in breathing and nausea. All individuals should avoid vigorous outdoor activity.

Level 2, Warning

Action: All of the level 1 warnings also apply to level 2. In addition, individuals with chronic respiratory and cardiac conditions should be advised to evacuate to a smoke-free environment, providing this can be done safely. Such an environment could be either away from the community or at a "clean" site within the community, such as a Red Cross shelter, or a school equipped with tight-fitting windows and doors and with adequate indoor air-filtration equipment. All other individuals should try to remain indoors with doors and windows closed, and avoid excessive exertion and exposure to cigarette smoke or other respiratory irritants.

Level 3, Emergency - Heavy Smoke Conditions

Action: Healthy individuals who choose to remain in the community should be advised to remain indoors, keep doors and windows closed, reduce activity, cut down on smoking and conserve energy. Persons that are uncomfortable should be advised to move out of the area or to a pre-designated "clean air" facility. Health care providers should also relocate those individuals with respiratory and/or cardiac problems, the elderly, infirm persons and young children to the “clean air” facility, following careful screening. Special consideration should be given to keeping family units together. Return of relocated persons should occur as soon as smoke conditions allow.

Re-Entry

Action: After the wildfire has been contained, and an "all-clear" declaration has been issued and public health alerts have been canceled, affected persons can return to the area.

4. PREVENTION OF FUTURE HEALTH-AFFECTING EVENTS

4.1 THE SOURCE: LAND USE AND FIRE POLICIES

In evaluating the 1997-98 fires and smoke episodes during an expert consultation the FAO evaluated those public policies which affect forest fires. The expert consultation concluded (FAO 1998):

The present status of national policy development in response to wildfires and land-use fires is often characterised by an ad hoc reaction to a situation that has already developed, rather than proactive mitigation before the emergency arises. Frequently policy development does not consider the underlying causes of fire incidence and spread, which may lie outside the forest sector. For example, rural poverty and deprivation or the effects of other public policies related to land use and incentives. Sometimes forest fire incidence and spread may be caused by ill-conceived forest management policies, in particular policies of total fire exclusion that have led to fuel accumulation and catastrophic fire outbreaks.

In general, land-use policy development is rarely based on reliable data on the forest-fire extent or causes. Nor has it involved consultative or participatory processes with those most closely involved and affected. Even where policies linked to reducing the incidence and damage of forest fires are in place, there may be institutional weaknesses that do not allow them to be enforced. These could arise from a shortage of public funding due to political instability or economic weaknesses.

Preliminary action needed to develop public policies related to fire management and sustainable land use practices:

There is a need for reliable and up-to-date systems for national, regional and global fire reporting, analysis and storage of data. Such data, and information on fire causes and socio-economic and environmental effects, are required as a sound basis for policy making. Linked to these is the requirement for international agreement on terms and definitions, as a basis for information sharing and communication.

Information on resource management alternatives and their consequences is essential for the involvement of all stakeholders in policy formulation and development.

Conclusions and recommendations to member countries regarding policy principles for sustainable land or forest use:

No single formula can cover the wide range of ecological, socio-economic, and cultural conditions that exist between and within regions, nor the different objectives that different societies will decide. Certain broad principles exist, however, that are common to all situations and objectives. These principles include the following:

- The formulation of national and regional policies specifically addressing forest fires, as an integral component of land-use policies, where they previously did not exist.

- Flexibility in policy implementation, and the capability to review and revise fire-related policies

- Clear and measurable policy objectives and implementation strategies are needed to minimise the many adverse effects of uncontrolled fires and to maximise the benefits from fire prevention, or from the controlled use of fire. Such objectives and implementation strategies would provide for sustainable land use practices, compatible inter-sectoral policies, joint fire management responsibilities at the community level, and the participation of the private sector and NGOs.

- Involvement of all stakeholders in policy development, especially through devolved or community forestry approaches. Recognition by decision-makers that sustainable land management may in many instances only be attained through devolution of control of forest resources and the involvement of the communities adjacent to or within forest in all aspects of management and fire protection. Such devolved approaches will require the revision of existing policies and laws and introduction of appropriate land-tenure arrangements to provide incentives for equitable local/community based participation in forest management and fire protection and control.

- A favourable policy environment must be created for all aspects of systematic fire management (prevention, detection, suppression, prescribed fire, post-fire rehabilitation etc.) and for an appropriate balance between prevention, suppression and prescribed fire use, based on local conditions. Such an environment should attempt to quantify the monetary and non-market values in order to emphasise the costs and benefits to society and to decision-makers.

- Policies are required for other forms of land-use; in particular credit policies should encourage land-use options that do not further contribute to deforestation.

- Policies that tend to increase forest fires must consider public health effects. Policies concerned with maintaining the health of ecosystems that are fire-adapted may have to balance public health and forest health issues.

Some technical aspects may support policy formulation and implementation. They include:

Systematic or Integrated Fire Management:

- ❑ devote more human and financial resources on fire prevention than at present in order to reduce the subsequent need and expense for fire suppression;

- ❑ policies should promote and regulate prescribed fire for a variety of land management purposes, including the reduction of hazardous fuels, and should promote public understanding of the purposes of prescribed burning. It should be noted, however, that prescribed fires are caused by humans and thus count as emissions against a country's carbon balance, while a disastrous fire that arises naturally because of a failure to reduce fuel loads does not (Kyoto Protocol; UN 1997).

- ❑ policies should define the process whereby fire management plans are developed to achieve the resource management objectives of conservation units;

- ❑ develop educational, extension, and public awareness programmes on fire in general and on policy-related matters in particular, appropriate to the needs of various stakeholders;

- ❑ vigorous training programmes in all aspects of fire management and at all levels including volunteer community fire-fighting brigades and the training of farmers in safe fire use;

- ❑ integration of fire management planning with inter-sectoral resource planning;

- ❑ encourage silvicultural practices that sustain healthy ecosystems which in turn reduce the impacts of fires;

- ❑ develop policies for a fire command structure that clearly delineates authorities and responsibilities of the various agencies involved;

- ❑ considering the threat from fires burning in radioactively contaminated vegetation a special fire management programme must be developed for the radioactively contaminated regions in Russia, Ukraine and Belarus with high priority. This would include also careful recording of data and experience for any future similar emergency.

Institutional Co-operation:

- ❑ encourage fire management cost-sharing among all relevant stakeholders at all levels

- ❑ develop inter-sectoral co-operation at national and local levels

- ❑ develop international agreements that facilitate the exchange of expertise

- ❑ develop capacity building in fire management

Restoration/rehabilitation:

- ☐ Salvage useable resources following fires;
- ☐ Encourage natural recovery through protection whenever possible for the purpose of maintaining genetic integrity;
- ☐ Undertake re-stocking where necessary;
- ☐ Restore the infrastructure and rehabilitate local communities.

Technology/Research/Information:

New technologies offer the means to introduce new and more environmentally and socially acceptable land use management policies; particular attention is drawn to “zero-burning” land clearing techniques.

Fire research at national and regional levels needs to be strengthened to support development of fire policies and fire management capabilities, especially related to investigations into socio-economic and cultural aspects of fire outbreaks. Fire research is needed into a number of topics:

- ☐ The development of new dedicated space-borne remote sensing technologies for improving decision support in fire management including sensor technologies for fire detection and early warning of fire.
- ☐ Post-fire recovery techniques and fire effects and ecosystem recovery processes.
- ☐ The impact of climate change on fire regimes and fire severity.

Existing experience should not be neglected, and local indigenous knowledge should be acquired on traditional fire-related cultures and customs as a guide for fire management practices and policies.

Evaluation systems should be developed to assess fire damage and benefits and to draw attention to the true costs and benefits of fires.

Policies and techniques that aim to increase agricultural productivity, while providing and enforcing disincentives for reckless programmes, will slow forest conversion for unsustainable agriculture and will thus reduce forest fire damage.

Conclusions and recommendations to International Organizations:

There are many international organisations, including FAO, UNDP, UNEP, WHO, WMO, other UN-agencies and non-governmental organizations (NGOs), involved in forest fire-related activities at global and regional levels. Continued and improved collaboration and co-ordination are urged. Transboundary or regional agreements for collaboration in fire management need to be developed, with the technical and financial support of international organisations.

International organisations are further urged to support the design and implementation of a global fire inventory or reporting system, in close collaboration with the fire science community and end-users. An internationally harmonized fire management terminology is required to support such global or regional fire reporting systems.

A global fire information system is needed to provide immediate access to real-time data and information on current fires, archived information, and other sources which are needed by countries to develop fire management programmes, increase preparedness and to respond to outbreaks at national, regional and global levels.

All interested International Organizations should play a catalytic role in the establishment of networks, to promote the sharing of information and knowledge and technical cooperation between developing countries. Sufficient resources should be allocated for these purposes.

Guidelines and codes of practice for fire prevention and control are also required, not only in the forest sector, but in any sector that could have an impact on forest fires (e.g. road alignments, power lines).

Technical assistance, from International Organizations, is still required, particularly in institutional support and capacity building.

Development of other Guidelines:

The International Tropical Timber Council (ITTC) identified forest fires as a major problem since it started operation in 1986. Pursuant to a decision of the ITTC, the International Tropical Timber Organisation (ITTO) undertook the development of a set of international guidelines for the protection of tropical forests against fire. This resulted in the publication "ITTO Guidelines on Fire Management in Tropical Forests" in 1996 (Annex E). The guidelines contain 29 principles and recommendations: Policy and Legislation, Strategies (Fire Management Planning, Fire Management Options, Fire Suppression, Role of Communities in Fire Protection), Monitoring and Research, Institutional Framework and Capacity Development, Socio-economic Considerations, Land Resources Management and Utilisation, and Training and Public Education.

At the FAO consultation "Public Policies Affecting Forest Fires" involving the regional group Europe and Temperate/Boreal Asia it was clearly recognised that the ITTO had taken a lead role in designing a framework for national fire management policies and strategies. Consequently the group recommended:

> *"Following the example of the ITTO Guidelines on Fire Management in Tropical Forests, the FAO is encouraged to support the development of similar guidelines for the boreal and temperate regions."*

The ITTO Guidelines on Fire Management in Tropical Forests are attached in Annex E.

4.2 RECOMMENDATIONS

- ☐ To assess the potential for national, regional, and global fire and smoke pollution, it is urgently required that the Global Vegetation Fire Inventory (GVFI) be implemented.

- ☐ Centres of Excellence need to be strengthened in their capabilities to monitor, archive, and disseminate information, and to forecast fire and related hazards.

- ☐ The UN agencies and other international organizations and programmes, particularly the WHO, WMO, FAO, UNEP, UNESCO, IDNDR, and ITTO, are urged to synergistically cooperate in the field of fire and smoke disaster prevention, management and mitigation.

- ☐ Special attention must be given to fire-generated radioactive emissions from terrain contaminated by radionuclides.

- ☐ Additional research is needed to develop source information for fires in different ecosystems, such as emission factors, emission ratios, and other data for flaming and smouldering combustion (e.g., particle size distribution, composition, toxicological properties, etc.). There is a need to determine the range of emission factors and emission ratios, as well as the variability and stability of the ratios and emission factors over time and by vegetation type.

- ☐ Additional research is needed on the physical/chemical factors contributing to changes during transport (local meteorology, plume concentration, etc.).

- ☐ Compilation of information pertaining to levels of exposure and fire activity is needed, in conjunction with past fire and smoke episodes.

- ☐ Research on mitigation approaches should be conducted. Specifically:

    - ➢ Assessment of the feasibility of different arrangements for “haze shelters” (in private homes, schools, hospitals, old age homes, and appropriate public buildings); and assessment of the actual haze protection provided by air filtration, sealing of rooms, etc.

    - ➢ Evaluation of the most effective approaches for managing future haze emergencies, in terms of arranging transport to “haze shelters” for vulnerable groups, provision of masks to key outdoor workers, and other mitigation methods.

    - ➢ Evaluation of the effectiveness of remaining indoors, including an assessment of the impact of outdoor particles on indoor air concentrations in different building types.

  - An assessment of the effectiveness of dust mask use by the general population, including a consideration of compliance by individuals in wearing masks, the fitting of masks, the effectiveness of the various types of masks that are available and the use of education to improve mask effectiveness.

  - An investigation of the availability of alternatives to masks which could be effective as personal protective equipment in mitigating health impacts.

- ☐ Research relating to the health impacts of biomass smoke:

  - The delineation of health impact mechanisms associated with biomass smoke.

  - Assessment of the impact of biomass smoke on mortality within the general population.

- ☐ Future work to elucidate health effects of vegetation fires should also address factors that influence health outcomes. The available literature for the most part focuses on total emissions and health; however, this is only a partial view of the range of issues involved in health effects from vegetation fires.

- ☐ Future work should include factors that affect exposure of populations to emissions from vegetation fires. Knowledge of the chemical and physical features of emissions that affect human exposures will allow for the prediction of disease or death in future fire episodes. For example, variations in vegetation and moisture content influence the release of carbon monoxide in different areas of the world.

- ☐ Future work to establish the biological mechanisms by which vegetation fire emmisions affect human health should be encouraged in the scientific community. This is necessary to determine the linkage between cause and effect, and will strengthen any results of ecological studies that have been done to date. Knowledge of biological plausibility will assist in identifying pertinent factors affecting human health in vegetation fires.

- ☐ The health community should be encouraged to look beyond its immediate area of expertise to explain health effects arising from vegetation fires. Fire episodes and responses to such events are multi-sectored; as such, they require a multidisciplinary approach for mitigating measures and for the prevention of future disease and death.

- ☐ The new approach of having national and local authorities make their own decisions about the levels of particulate matter, and about public advisory or mitigation activities, may be difficult at the beginning. It may require special explanation and a workshop to address this issue.

- ☐ A working group may be needed to reach agreement on the levels of particles that should trigger international action for vegetation fire preparedness and control.

- ☐ These Health Guidelines for Vegetation Fire Events should be updated every few years to reflect new scientific evidence on particulate matter and health effects.

Annex A

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Annex – B

LIST OF ACRONYMS

ADB	Asian Development Bank, Manila, Philippines
ACURATE	Atlantic Coast Unique Regional Atmospheric Tracer Experiment
AGU	American Geophysical Union, Washington DC, USA
AMIS	Air Management Information System (WHO, Healthy Cities)
ANATEX	Across North America Tracer EXperiment
API	Air Pollution Index
ASCII	American Standard Code for Information Interchange
ASEAN	Association of South East Asian Nations, Tokyo, Japan
ASMA	Alam Sekitar MAlaysia Sdn Bhd, Kuala Lumpur, Malaysia
ASMC	ASEAN Specialized Meteorological Center
ATM	Atmospheric Transport Model
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BIBEX	BIomass Burning Experiment (IGBP-IGAC)
BIRD	Bispectral InfraRed Detection microsatellite mission (DLR)
BLM	US Bureau of Land Management
B[a]P	Benzo[a]pyrene
CADR	Clean Air Delivery Rate
CAPTEX	Cross Appalachian Tracer EXperiment
CAS	Commission for Atmospheric Sciences of the WMO
CDAS	Climate Data Assimilation System
CEN	European Committee for Standardization
CEPIS	Pan American Center for Sanitary Engineering and Environmental Sciences
CFC	ChloroFluoroCarbon
CFR	Code of Federal Regulations
CH_4	Methane
CIFOR	Center for International FOrestry Research
CMD	Cyclopedic Medical Dictionary
CO	Carbon monoxide
CO_2	Carbon dioxide
COPD	Chronic Obstructive Pulmonary Disease
CP	Conference of the Parties
CSA	Canadian Space Agency
CSD	Commission for Sustainable Development
CSIRO	Commonwealth Scientific & Industrial Research Organization
CSR	Centro de Sensoriamento Remoto of IBAMA (Centre for Remote Sensing)
CTBT	Comprehensive Test Ban Treaty
DAO	Data Assimilation Office at NASA's Goddard SFC, Maryland, USA
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DSMP	Defense Meteorological Satellite Programme
EC DG	European Commission Directorate General
ECE	Economic Commission for Europe

ECMWF	European Center for Medium Range Weather Forecasts
ECPC	Experimental Climate Prediction Center
EDC	EROS Data Center
EEPSEA	Economy and Environment Program for SE Asia
EHA	Emergencies and Humanitarian Action, WHO, PHE, Geneva
ENSO	El Niño Southern Oscillation
EOSDIS	Earth Observing System Data and Information System
EOS-AM1	Earth Observing System satellite (now TERRA; with images from orbits at 10 am)
EOS-PM1	Earth Observing System satellite (with images from orbits at 1 pm)
ERA	ECMWF Re-analysis Archive
EROS	Earth Resources Observation System of the USGS
ERS	ESA Remote Sensing Satellite
ESA	European Space Agency
ESRIN	European Space Research Institute
ETEX	European Tracer EXperiment
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCCC	Framework Convention on Climate Change
FGGE	First GARP Global Experiment
GARP	Global Atmospheric Research Programme (WMO)
GAW	Global Atmosphere Watch
GEF	Global Environmental Facility
GEMINI	Global Emergency Management Information Network Initiative
GEMS	Global Environmental Monitoring System (UNEP/WHO)
GFMC	Global Fire Monitoring Center
GIS	Geographic Information System
GLAS	Geoscience Laser Altimeter System
GOES	Geostationary Operational Environmental Satellite
GRIB	GRIdded Binary format
GURME	GAW Urban Research Meteorology and Environment
HCHO	Formaldehyde
HM	Heavy Methane tracer
HNO_3	Nitric acid
H_2S_2	Hydrogen disulphide
HSF	Human Space Flight
IAEA	International Atomic Energy Agency, Vienna, Austria
IBAMA	Instituto Brasileiro Meio Ambiente Recursos Naturais Renováveis (Brazilian Institute for the Environment and Renewable Natural Resources)
IBFRA	International Boreal Forest Research Association
ICAO	International Civil Aviation Organization
IDNDR	International Decade for Natural Disaster Reduction
IGAC	International Global Atmospheric Chemistry (Project)
IGBP	Inernational Geosphere Biosphere Programme
ILO	International Labour Office, Geneva, Switzerland
ITTA	International Tropical Timber Agreement
ITTC	International Tropical Timber Council
ITTO	International Tropical Timber Organization
IUFRO	International Union of Forestry Research Organizations

INPE-CPTEC	Instituto de Pesquisas Especiais (Civil Aerospace Agency of Brazil, Sao José dos Campos, São Paulo, Brazil)
IPF	Imagery Processing Facility
IR	Infra Red radiation
ISO	International Standards Organization
ISS	International Space Station
ITTC	International Tropical Timber Council
ITTO	International Tropical Timber Organization
JPL	Jet Propulsion Laboratory
JRC	Joint Research Centre, Ispra
LANDSAT	LAND (Remote Sensing) SATellite
LIDAR	Light Detection And Ranging instrument
LST	Land-Surface Temperature
MAPS	Measurement of Atmospheric Pollution from Satellites
METEOSAT	METEOrological SATellite
MIDAS	Manchester Information Datasets and Associated Services
MIR	Russian “Peace” space station
MISR	Multi-angle Imaging Spectro-Radiometer
MODIS	Moderate Resolution Imaging Spectro-radiometer
MOPITT	Measurement Of Pollution In The Troposphere
MTV	Monitoring of the Tropical Vegetation
NAAQS	National Ambient Air Quality Standard
NASA	National Aeronautics and Space Administration (United States)
NASDA	NAtional Space Development Agency (Japan)
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction (formerly NMC)
NDVI	Normalized Difference Vegetation Index
NGO	Non Governmental Organization
NH_3	Ammonia
NHAP	National Haze Action Plan
NIOSH	National institute for Occupational Safety and Health
NMC	National Meteorological Center
NMHS	National Meteorological and Hydrological Service
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration of the United States
NO_x	Nitrogen oxides
NWP	Numerical Weather Prediction
O_3	Ozone
OCTS	Ocean Color and Temperature Scanner
OEH	Occupational and Environmental Health, WHO, PHE, Geneva
OH	Hydroxyl radical
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic (Polynuclear) Aromatic Hydrocarbons
PAHO	Pan American Health Organization
PARTS	Programme to Address ASEAN Regional Transboundary Smoke
PFT	Per-Fluorocarbon Tracer
PHE	Department for Protection of the Human Environment, WHO, Geneva
PM	Particulate matter with no regard to size of particles

PM_{10}	Concentration of particles with aerodynamic particle diameters of less than 10 micrometers.
$PM_{2.5}$	Concentration of particles with aerodynamic particle diameters of less than 2.5 micrometers.
POLDER	POLarization and Directionality of the Earth's Reflectances
PROARCO	PROgrama de Prevenção e Controle de Queimadas e de Combate aos Incêndios Florestais no ARCO do Desflorestamento da Amazônia
PSI	Pollutant Standard Index of USEPA
QA/QC	Quality Assurance/Quality Control
RADARSAT	Canadian Earth observation satellite (Canadian Space Agency/Canada Center for Remote Sensing) with SAR equipment.
REM	Radioactivity Environmental Monitoring data bank at JRC, Ispra
RHAP	Regional Haze Action Plan
RISO	Riso Research Institute, Roskilde, Denmark
RSMC	Regional Specialized Meteorological Centers of the WMO
SAFARI	Southern Africa Fire-Atmosphere Research Initiative
SAG	Scientific Advisory Groups in the GAW programme
SAR	Synthetic Aperture Radar (a high-rate imaging technique)
SBRS	Santa Barbara Remote Sensing
SFC	Space Flight Center
SO_2	Sulphur dioxide
SOP	Standard Operating Procedure
SPOT	Système Pour l'Observation de la Terre
STARE	Southern Tropical Atlantic Regional Experiment
TEOM	Tapered Element Oscillating Microbalance
TOMS	Total Ozone Mapping Spectrometer
TRACE-A	Transport of Atmospheric Chemistry Experiment – Africa
TRACT	Transport of Air Pollutants over Complex Terrain
TRANSALP	TRANSALPine atmospheric transport simulation
TRMM	Tropical Rainfall Measuring Mission
TSP	Total Suspended Particles
TWA	Time Weighted Average concentration of emission for determining the level of exposure
UK	United Kingdom
UN	United Nations
UNCED	United Nations Conference on Environment and Development (Rio de Janeiro, June 1992)
UNDP	United Nations Development Programme
UNDRO	United Nations Disaster Relief Organization (not operational any more)
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USEPA	United States Environmental Protection Agency
USA	United States of America
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UTC	Universal Time, Coordinated (formerly Greenwich Mean Time)
UV	Ultra Violet radiation
VIS	VISible imagery

VOC	Volatile Organic Compounds
WHO	World Health Organization
WMO	World Meteorological Organization
WWF	World Wide Fund for Nature

Annex C

GLOSSARY

Selected important wildland fire management terms are given in the following. Some of them are taken from the United Nations Wildland Fire Management Terminology (FAO 1986) and has been modified for this document (see also Pyne et al. (1996) and Goldammer et al. (1998))

Adiabatic lapse rate	Theoretical temperature lapse rate of a parcel of air, which moves adiabatically in the vertical (WMO, 1992).
Adverse effect	Change in morphology, physiology, growth, development or life span of an organism which results in impairment of functional capacity or impairment of capacity to compensate for additional stress or increase in susceptibility to the harmful effects of other environmental influences (WHO, 1994).
Aerial fuels	The standing and supported forest combustibles not in direct contact with the ground and consisting mainly of foliage, twigs, branches, stems, bark, lianas and other vines. In general they easily dry out and may carry surface fires into the canopy (FAO, 1986; ITTO, 1997).
Aerosol	A suspension in a gaseous medium of solid particles, liquid particles or solid and liquid particles having a negligible falling velocity (ISO, 1994).
Asthma	A disease caused by increased responsiveness of the tracheobronchial tree to various stimuli, which results in paroxysmal constriction of the bronchial airways (CMD, 1997). Also see paroxysm.
Biomarker	Any parameter that can be used to measure an interaction between a biological system and an environment agent, which may be chemical, physical or biological (WHO, 1993).
Biomass	Organic substance of biotic origin: either living organisms or dead substances such as wood, crop residues, or animal dung.
Biomass smoke	Term used for convenience for the smoke generated by burning biomass.
Biotic	Of or relating to life (Webster, 1994).
Broadcast burning	Allowing a prescribed fire to burn over a designated area within well defined boundaries for reduction of fuel hazard, as a

	silvicultural treatment, or both (FAO, 1986; ITTO, 1997).
Bronchi	The two main branches leading from the trachea to the lungs, providing a passageway for air (CMD, 1997).
Bronchial tube	One of the smaller subdivisions of the bronchi (CMD, 1997).
Bronchiole	One of the smaller subdivisions of the bronchial tube (CMD, 1997).
Bronchiolitis	Inflammation of the bronchioles (CMD, 1997).
Bronchitis	Inflammation of the mucous membrane of the bronchial airways (CMD, 1997)
Bronchodilator	A drug that expands the bronchial tubes by relaxing bronchial muscle (CMD, 1997).
Carbon dioxide	A colourless, odourless, noncombustible gas, formula CO_2. It is approximately 50% heavier than air, of which it is a normal constituent. It is formed by certain natural processes (see carbon cycle) and by the combustion of fuels containing carbon, and it has been estimated that the amount in the air is increasing by 0.27% annually. Only in the most exceptional circumstances do local concentrations of carbon dioxide in air rise to levels that are dangerous to health, but it plays a significant role in the decay of building stones and in corrosion (WHO, 1980).
Carbon monoxide	A colourless, almost odourless, tasteless, flammable gas, formula CO. It is produced, *inter alia*, by the incomplete combustion of organic materials (e.g. in automobile engines) and normally occurs in trace amounts in the atmosphere. At concentrations exceeding about 100 cm^3/m^3 (0.01%) it is highly toxic. Its affinity for haemoglobin (with which it forms carboxyhaemoglobin) is between 200 and 300 times that of oxygen, and it has the effect of reducing the oxygen-transport capacity of haemoglobin and leading to death by asphyxiation. Concentrations of carbon monoxide in city streets (arising mainly from motor vehicle exhausts) can be sufficiently high to cause concern, as can those resulting from tobacco smoking in unventilated rooms (WHO, 1980).
Cardiovascular	Pertaining to the heart and blood vessels (CMD, 1997).
Chlorofluorocarbon(s)	Organic compound(s) derived from the complete substitution of the hydrogen atoms in methane and ethane with both fluorine and chlorine atoms. They are colourless, odourless gas (es) containing carbon, chlorine and fluorine, acronym CFC; extremely stable in the troposphere, but unstable in the

	stratosphere. Some of them are known to contribute to the depletion of ozone in the stratosphere (WHO, 1990).
Chronic obstructive Pulmonary disease (COPD)	A disease process that decreases the ability of the lungs to perform ventilation. Diagnostic criteria include a history of persistent dyspnea on exertion, with or without chronic cough, and less than half of normal predicted maximum breathing capacity. Diseases that cause this condition are chronic bronchitis, pulmonary emphysema, chronic asthma, and chronic bronchiolitis (CMD, 1997).
Climate	Synthesis of weather conditions in a given area, characterised by long-term statistics (mean values, variances, probabilities of extreme values, etc.) of the meteorological elements in that area (WMO, 1992).
Climate forcing	A power exerting a perturbation of the climate.
Combustion	A chemical reaction in which a material combines with oxygen with the evolution of heat: "burning". The combustion of fuels containing carbon and hydrogen is said to be complete when these two elements are all oxidised to carbon dioxide and water. Incomplete combustion may lead to (1) appreciable amounts of carbon remaining in the ash; (2) emission of some of the carbon as carbon monoxide; and (3) reaction of the fuel molecules to give a range of products of greater complexity than that of the fuel molecules themselves (if these products escape combustion they are emitted as smoke) (WHO, 1980).
Condensation	1. The transition from the gaseous to the liquid state. 2. The physical process by which water vapour is transformed into dew, fog or cloud droplets (WMO, 1992)
Condensation nucleus	Nucleus on which water vapour can condense (WMO, 1992)
Coning	Formation of a pollution plume which trails downwind of a source in the form of a cone. This normally occurs when the environment has near-neutral stability (WMO, 1992).
Control a Fire	To complete a control line around a fire, any spot fires therefrom, and any interior islands to be saved, and cool down all hot spots that are immediate threats to the control line, until the line can reasonably be expected to hold under foreseeable conditions (ITTO, 1997).
Convection	Organised internal motions within a layer or air, leading to vertical transport of heat, momentum, etc. (WMO, 1992). In air, the convection most commonly occurs as the result of the

	buoyancy of a mass of air in contact with a hot surface, which leads to a vertical current of air above that surface. Convection may also occur by means of air currents and eddies that are set up mechanically, as when air passes over high ground.
Convective storm	Storm with strong vertical air mass movements (FAO, 1986).
Counter fire	Fire set between main fire and backfire to hasten spread of backfire. Also called draft fire. The act of setting counter fires is sometimes called front firing or strip firing (FAO, 1986; ITTO, 1997).
Crown fire	A fire that advances from top to top of trees or shrubs more or less independently of the surface fire (FAO, 1986; ITTO, 1997).
Deposition	Removal of contents of air masses onto a substrate, usually the surface.
Diameter, equivalent	The diameter of a spherical particle of the same density that, relative to a given phenomenon or property (e.g., free-falling velocity; surface area; volume; and aerodynamic properties) would behave as the particle under investigation (Willeke, 1993).
Disease	A pathological condition of the body that presents a group of clinical signs, symptoms, and laboratory findings peculiar to it and setting the condition apart as an abnormal entity differing from other normal or pathological condition (CMD, 1997).
Drought	Prolonged absence or marked deficiency of precipitation (WMO, 1992)
Dry adiabatic lapse rate	Adiabatic lapse rate of dry air, and also, very closely, of moist unsaturated air. Its value is about 10^0C/km (ISO, 1994; WMO, 1992).
Dry deposition	Removal of contaminants of air onto a substrate without involvement of rain, clouds or fog.
Dust	Small solid particles, conventionally taken as those particles below 75 μm in diameter, which settle out under their own weight but which may remain suspended for some time (ISO, 1994). National standards may be more specific and include particle diameters or a definition in terms of a sieve of specified aperture. Dust occurs in the atmosphere both naturally and as a result of the activities of man (Willeke, 1993).
Dyspnea	Air hunger resulting in labored or difficult breathing, sometimes accompanied by pain (CMD, 1997).

Early burning	Prescribed burning early in the dry season before grass, tree leaves and undergrowth are completely dry or before the leaves are shed, as an insurance against more severe fire damage later on (ITTO, 1997).
Emergency Department	The portion of a hospital that treats patients experiencing an emergency (CMD, 1997).
Emergency room	A seldom used term for Emergency Department (CMD, 1997).
Emphysema	A chronic pulmonary disease marked by an abnormal increase in the size of air spaces distal (farthest from the centre) to the terminal bronchioles with destructive changes in their walls (CMD, 1997)
Expiration	Expulsion of air from the lungs in breathing. Normally the duration of expiration is shorter than that of inspiration. In general, if expiration lasts longer than inspiration, a pathological condition such as emphysema or asthma is present (CMD, 1997).
Exposure	Exposure to a chemical is the contact of that chemical with the outer boundary of the human body. The outer boundary of the human body is the skin and the openings into the body such as the mouth, the nostrils, and punctures and lesions in the skin (WHO, 1999).
Exposure assessment	Quantitative or qualitative evaluation of the contact of a chemical with the outer boundary of the human body, which includes consideration of the intensity, frequency and duration of contact, the route of exposure (e.g. dermal, oral or respiratory), rates (chemical intake or uptake rates), the resulting amount that actually crosses the boundary (a dose), and the amount absorbed (internal dose) (WHO, 1999).
Fanning	Formation of a pollution plume that expands sideways much more than in the vertical. The sideways spread is often caused by a change of wind direction with height while the vertical spread is inhibited by thermal stability (WMO, 1992).
Fine particles	Particles with aerodynamic diameters below 2.5 micrometer.
Firebreak	Any natural or constructed discontinuity in a fuel-bed utilised to segregate, stop, and control the spread of fire or to provide a control line from which to suppress a fire; characterised by complete lack of combustibles down to mineral soil (as distinguished from fuelbreak) (FAO, 1986; ITTO, 1997).
Fire danger rating	A component of a fire management system that integrates the

	effects of selected fire danger factors into one or more qualitative or numerical indices of current protection needs (ITTO, 1997).
Fire hazard	A fuel complex, defined by volume, type, condition, arrangement, and location, that determines the degree both of ease of ignition and of fire suppression difficulty (FAO, 1986; ITTO, 1997).
Fire intelligence	All infrastructures, communication, base data and other hard- and software that provide the inputs to an information and decision-support system in fire management (ITTO, 1997).
Fire management	All activities required for the protection of forest values from fire and the use of fire to meet land management goals and objectives (FAO, 1986; ITTO, 1997).
Fire prevention	All measures in fire management, forest management, forest utilisation and concerning the land users and the general public that may result in the prevention of outbreak of fires or the reduction of fire severity and spread (ITTO, 1997).
Fire retardant	Any substance except plain water that by chemical or physical action reduces the flammability of fuels or slows their rate of combustion, e.g., a liquid or slurry applied aerially or from the ground during a fire suppression operation (FAO, 1986; ITTO, 1997).
Fog	As international standard fog is a general term applied to a suspension of droplets in a gas. In meteorology, it refers to a suspension of water droplets resulting in a visibility of less than 1 km (ISO, 1994). WMO defines fog as a suspension of very small, usually microscopic water droplets in the air, generally reducing the horizontal visibility at the earth’s surface too less than 1 km (WMO, 1992).
Forced expiratory Volume (FEV)	The volume of air that can be expired after a full inspiration. The expiration is done as quickly as possible and the volume measured at precise times; at ½, 1, 2 and 3 seconds. This provides valuable information concerning the ability to expel air from the lungs (CMD, 1997).
Forest residue	The accumulation in the forest of living or dead, mostly woody material that is added to and rearranged by human activities such as forest harvest, cultural operations, and land clearing (FAO, 1986; ITTO, 1997).
Fuel	All combustible organic material in forests and other vegetation types, including agricultural systems (ITTO, 1997).

Fuelbreak	Generally wide (20 - 300 meters) strips of land on which either less flammable native vegetation is maintained and integrated into fire management planning, or vegetation has been permanently modified so that fires burning into them can be more readily controlled (as distinguished from firebreak). Some fuelbreaks contain narrow firebreaks which may be roads or narrower hand-constructed lines. During fires, these firebreaks can quickly be widened either with hand tools or by firing out. Fuelbreaks have the advantages of preventing erosion, offering a safe place for fire fighters to work, low maintenance, and a pleasing appearance.
Fume	Aerosol of solid particles, usually from metallurgical processes, generated by condensation from the gaseous state, generally after volatilisation from melted substances and often accompanied by chemical reactions such as oxidation (ISO, 1994). By extension, also the gases charged by particles resulting from a chemical process or a metallurgical operation (WHO, 1980). Often used in the plural, *fumes* for visible clouds of gases, vapours, or aerosols that have an unpleasant and malodorous smell (WHO, 1980; ISO, 1994).
Function	The act of carrying on or performing a special acivity. Normal function is the normal action of an organ. Abnormal activity or the failure of an organ to perform its activity is the basis of disease or disease processes (CMD, 1997).
Ground fire	A fire burning in organic terrain, e.g. dried tropical swamps and peat layers (ITTO, 1997).
Haze	A suspension in the atmosphere of extremely small (dry) particles, individually invisible to the naked eye, but which are numerous enough to give the atmosphere an appearance of opalescence together with reduced visibility (ISO, 1994, WMO 1992).
Heat	Means both thermal energy and thermal energy transfer.
Hydrocarbon	An organic compound containing only the elements carbon and hydrogen. The carbon atoms may be arranged either in open-ended chains, which may or may not be branched or in closed rings. There are two types of ring hydrocarbons: *alicyclic compounds*, consisting of three or more carbon atoms arranged in a closed ring (and whose properties are similar to those of the open-chain compounds of the same molecular mass), and aromatic compounds. The molecular structure of aromatic compounds is based on that of benzene, the simplest member of the class, which contains six carbon atoms joined by three single

	and three double carbon-carbon bonds. Such compounds are described as *polycyclic* if they contain two or more rings; the term “polynuclear” (as in “polynuclear aromatic hydrocarbon”, frequently abbreviated as PAH) is also used. The major constituents of gasoline and other petroleum fuels are hydrocarbons of the open-chain type. These compounds are not considered to be a hazard to health even at the concentrations at which they are encountered in city air. Many aromatic hydrocarbons, on the other hand, are highly toxic (WHO, 1980; WHO, 1997). Well known examples of polycyclic aromatic hydrocarbons are anthracene, naphthalene, and benzo[a]pyrene (WHO, 1980).
Hydrogen	A colourless, odourless, inflammable gas, which combines chemically with oxygen to form water; formed also in combustion plumes (WHO, 1980).
Hydroxyl radical	Univalent radical containing hydrogen and oxygen, OH, extremely effective oxidant in the atmosphere
Illness	The state of being sick (CMD, 1997).
Infrared light	Invisible rays of the spectrum lying outside the red end of the visible spectrum, radiated by heat
Inversion layer	Atmospheric layer in which the temperature increases or remains constant with height (WMO, 1992).
Ladder fuels	Fuels, which provide vertical continuity between strata. Fire is able to carry from surface fuels into the crowns of trees or shrubs with relative ease and help assure initiation and continuation of crown fires (FAO, 1986; ITTO, 1997).
Lapse rate	The rate of change of any meteorological element with height (WMO, 1992).
Lofting	A pollution plume with a flat base but appreciable vertical spread indicative of an atmosphere which is statically stable up to the base of the plume and unstable above (WMO, 1992)
Looping	Formation of a pollution plume which is distorted by large vertical eddies in an unstable atmosphere (WMO, 1992)
Low birth weight	Abnormally low weight of a newborn, usually below 2000 g (CMD, 1997).
Lower respiratory symptom	Symptom in the lower respiratory tract (i.e. the respiratory tract from trachea to bronchioles).

Lung cancer	Cancer that may appear in thr trachea, air sacs and other lung tubes. It may appear as an ulcer in the windpipe, as a nodule or small flattened lump, or on the surface blocking air tubes. It may extend into the lymphatics and blood vessels (CMD, 1997).
Mass fire	A fire resulting from many simultaneous ignitions. These fires generate high levels of energy output (FAO, 1986; ITTO, 1997).
Methane	A colourless, odourless gas, formula CH_4. It is flammable and forms explosive mixtures with air. Methane is the principal constituent of most natural gas and a major constituent of coal gas. It is formed in the decomposition of organic matter, e.g. in marshes, and a common term for it is "marsh gas" (WHO, 1980).
Mist	Loose term applied to a suspension of droplets in a gas. In meteorology it relates to visibility of less than 2 km but greater than 1 km (ISO, 1994). See also fog.
Mixed layer	Layer adjacent to the earth's surfacewhich is mixed by convection or frictionally-induced turbulence or both (WMO, 1992).
Morbidity	The number of sick persons or cases of disease in relationship to a specific population (CMD, 1997).
Mortality	The death rate; the ratio of the number of deaths to a given population (CMD, 1997).
Nitrate	See *nitric acid.*
Nitric acid	A colourless or yellowish fuming liquid, formula HNO_3. It is highly corrosive and the vapour is very hazardous. Nitric acid and nitrates (mainly ammonium nitrate) occur in the atmosphere in the form of aerosols: the acid is formed from oxides of nitrogen and then reacts with ammonia to form ammonium nitrate (WHO, 1997).
Nitric oxide	See *nitrogen oxides.*
Nitrogen	A gaseous element, atomic number 7, relative atomic mass 14.0067, symbol N. It is the principal constituent of air (78% by volume).
Nitrogen dioxide	See *nitrogen oxides.*
Nitrogen oxides	A series of seven compounds, of which only three are of any significance in the atmosphere. *Dinitrogen oxide* (nitrous oxide), formula N_2O, is a colourless gas that is believed to play an important role in the nitrogen cycle. It is the most abundant

	atmospheric nitrogen compound and a greenhouse gas but is of no significance as a pollutant. *Nitrogen oxide* (nitric oxide), formula NO, is a colourless poisonous gas that reacts readily with oxygen (and very rapidly with ozone) to form the dioxide. It is formed in combustion processes, e.g., in furnaces and internal combustion engines. NO is an active participant in the atmospheric reactions that lead to the production of *photochemical smog*. Nitrogen dioxide, formula NO_2, is a reddish-brown poisonous gas. At ordinary temperatures the vapour is an equilibrium mixture of NO_2 and the dimer N_2O_4 (dinitrogen tetroxide); on heating, the latter dissociates and the NO_2 content increases. Above 140^0C, the NO_2 dissociates into NO and oxygen (WHO, 1997). In the air pollution literature, the term “nitrogen oxides” and the formula NO_x are used for the mixture of NO and NO_2 in the air (WHO, 1997).
Nucleus	A particle of any nature upon which molecules of water or ice accumulate as a result of a phase change to a more condensed state (WMO, 1992).
Outpatient	One who receives treatment at a hospital, clinic, or dispensary but is not hospitalised (CMD, 1997).
Oxidation	A transformation of an organic substrate that can be rationally dissected into steps or primitive changes. The latter consist in removal of one or several electrons from the substrate followed or preceded by gain or loss of water and/or hydrons or hydroxide ions, or by nucleophilic substitution by water or its reverse and/or by an intramolecular molecular rearrangement (IUPAC, 1997).
Oxidant (in atmospheric chemistry)	A very qualitative term which includes any and all trace gases which have a greater oxidation potential than oxygen (for example ozone, peroxyacetyl nitrate, hydrogen peroxide, organic peroxides, NO_3, etc.). It is recommended that alternative, more definitive terms be used which define the specific oxidant of interest whenever possible (IUPAC, 1997).
Oxygen	A gaseous element, atomic number 8, relative atomic mass 15.9994, symbol O. Oxygen is a colourless, odourless gas which supports combustion in air. Molecular oxygen (O_2) constitutes 20.95% by volume of dry air in the lower part of the atmosphere. O_2 is essential for the maintenance of almost all forms of life. Above an altitude of 20 km atomic oxygen appears in significant amounts and at 100 km it is in the predominant form. For the tri-atomic form of oxygen, see *ozone*.

Ozone	The tri-atomic allotrope of oxygen; a pale blue gas with a distinctive pungent odour, formula O_3. It is a highly reactive oxidising agent and is very poisonous, and is considered a serious pollutant at concentrations much in excess of 125 $\mu g/m^3$ (WHO, 1980). It is naturally occurring in the atmosphere. It occurs at large concentrations in the upper atmosphere, where it is formed by the action of solar ultraviolet radiation. In the troposphere, ozone is mostly formed by photochemical reactions involving hydrocarbons and nitrogen oxides.
Ozone layer	An atmospheric layer lying between about 10 and 50 km (above the surface of the earth), in which the percentage of ozone is relatively high. The maximum concentration generally occurs about 20 or 25 km (WMO); it acts as an effective shield for the solar ultraviolet rays (WHO, 1980).
Paroxysm	A sudden, periodic attack or recurrence of symptoms of a disease; an exacerbation of the symtoms of a disease (CMD, 1997)
Particle	Small discrete mass of solid or liquid matter (ISO, 1994).
Particle aerodynamic diameter	Diameter of a sphere of density 1 g/cm^3 with the same terminal velocity due to gravitational force in calm air as the particle, under the prevailing conditions of temperature, pressure and relative humidity (ISO, 1995).
Particle size analysis	The science, which deals with the measurement of the dimensions and the determination of the shape of particles; the whole of the operations by which a particle size distribution can be obtained (Willeke, 1993).
Particle size distribution	The distribution of equivalent diameters of particles in a sample or the proportion of particles for which the equivalent diameter lies between defined limits (Willeke, 1993).
Particulate matter, suspended	All solid and liquid particles in the air that are small enough not to settle out on to the earth’s surface under the influence of gravity; also defined as the material that can be removed from the air by passing it through a suitable filter (Willeke, 1993). See also: *aerosol; dust*.
Peak expiratory flow rate	See rate.
Photochemical smog	Result of reactions in the atmosphere between nitrogen oxides, organic compounds and oxidants under the influence of sunlight, leading to the formation of oxidising compounds or possibly

	causing poor visibility, eye irritation or damage to material and vegetation if sufficiently concentrated (ISO, 1994).
Plume	Identifiable stream of air with a temperature or composition different from that of its environment. Examples are the smoke plume from a chimney and a buoyant plume rising by convection from heated ground (WMO, 1992).
Plume rise	Height of the centreline of a plume above the level it was emitted to the atmosphere (ISO, 1994).
Polycyclic aromatic Hydrocarbon	See hydrocarbon
Polynuclear aromatic hydrocarbon	See hydrocarbon
Precipitation	Hydrometeor consisting of a fall of an ensemble of particles. The forms of precipitation are: rain, snow, snow grains, snow pellets, diamond dust, hail and ice pellets (WMO, 1992).
Pre-attack planning	Fire planning within designated blocks of land, covering the following items: locations of fire lines, base camps, water sources, helispots, transportation systems, probable rates of travel, constraints of travel on various types of attack units, determining of construction of particular fire lines, the probable rate of line construction, topographic constraints on line construction, etc. (ITTO, 1997).
Prescribed burning	Controlled application of fire to vegetation in either their natural or modified state, under specified environmental conditions which allow the fire to be confined to a predetermined area and at the same time to produce the intensity of heat and rate of spread required to attain planned resource management objectives (FAO, 1986; ITTO, 1997).
Prescribed fire	A fire burning within prescription. The fire may result from either planned or unplanned ignitions
Pre-suppression planning	All measures of fire intelligence and preparedness for fire suppression actions (ITTO, 1997).
Rain	Precipitation of liquid water particles, either in the form of drops of more than 0.5 mm in diameter, or of smaller widely scattered drops (WMO, 1992).
Rate	The speed or frequency of occurrence of an event, usually expressed with respect to time or some other known standard

	(CMD, 1997). *Death rate* or *mortality rate* is the number of deaths in a specified population, usually expressed per 100 000 population, over a given period, usually 1 year. *Morbidity rate* is the number of cases per year of certain diseases in relation to the population in which they occur. *Infant mortality rate* is the number of deaths per year of live-born infants less than 1 year of age divided by the number of live births in the same year. *Peak expiratory flow rate* is the maximum rate of exhalation during forced expiration, measured in liters per second or liters per minute.
Relative humidity of moist Air with respect to water	The ratio of the mole fraction of the water vapour in the air to the corresponding mole fraction if the air were saturated with respect to water at a particular pressure and temperature (WMO, 1992) Also see *humidity*.
Remote sensing	Determination of substances in the atmosphere, or of emissions, or of meteorological parameters in the atmosphere, by means of instruments not in immediate physical contact with the sample being examined (ISO, 1994). According to WMO, remote sensing is defined as the collection and recording of data from a distant point, e.g. radar and satellite-based observations of the atmosphere as opposed to on-site (in situ) sensing (WMO, 1992).
Residence time (atmospheric)	The average time a molecule or aerosol spends in the atmosphere after it is released or generated there. For compounds with well defined sources and emission rates, this is estimated by the ratio of the average global concentration of a substance to its production rate on a global scale. It is a function of not only the emission rates but the loss rates by chemical and physical removal processes. (IUPAC, 1997).
Respiration	The act of breathing (i.e. inhaling and exhaling) during which the lungs are provided with air through inhaling and carbon dioxide is removed through exhaling (CMD, 1997).
Respirator	Special masks designed for the protection of workers exposed to occupational health hazards.
Respiratory	Pertaining to respiration (CMD, 1997).
Sampling	The collection of a representative portion for analysis and testing (WHO, 1980). *Continuous sampling* is sampling, without interruptions, throughout an operation or for a predetermined time. *Grab sampling* or *spot sampling* is the taking of a sample in a very short time (ISO, 1994).

Smog	Fog having a high pollution content (WMO, 1992). Also see *photochemical smog*.
Smoke	An aerosol originating from combustion, thermal decomposition or thermal evaporation. Its particles may be solid (magnesium oxide smoke) or liquid (tobacco smoke) (IUPAC, 1997). The International Standard definition of smoke is that of a visible aerosol usually resulting from combustion (ISO, 1994). WMO defines smoke as a suspension in the atmosphere of small particles produced by combustion (WMO, 1992).
Smoke abatement	Legal measures that may be taken on community, regional, or national level to control smoke emissions and thus reduce pollution by smoke ((FAO, 1986; ITTO, 1997).
Smoke control	See *smoke abatement*.
Smoke management	The application of knowledge of fire behaviour and meteorological processes to minimise air quality degradation during prescribed fires.
Soot	A randomly formed carbonaceous particulate matter that may be coarse, fine and/or colloidal in proportions depending on its origin. Soot consists of varibale quantities of carbonaceous and inorganic solids together with absorbed and occluded tars and resins. Notes: An unwanted by-product of incomplete combustion or pyrolysis. Soot generated within flames consists essentially of aggregates of spheres of cartbon. Soot found in domestic fireplaces chimneys contains few aggregates but may contain substantial amounts of particulate fragments of coke or char. Soot from diesel engines consists essentially of aggregates together with tars and resins.
Spirometry	Measurement of the air capacity of the lungs (CMD, 1997).
Surface fire	Fire that burns only surface litter, other loose debris of the forest floor, and small vegetation (FAO, 1986; ITTO, 1997).
Symptom	Any perceptible change in the body or its functions that indicates disease or the kind or phases of disease (CMD, 1997).
Temperature inversion	Vertical temperature distribution such that temperature increases with height (WMO, 1992).
Trachea	A cylindrical tube from the larynx to the primary bronchi (CMD, 1997).

Tropical dry forest	Open forest with continuous grass cover, distinguished from other tropical forests by distinct seasonality and low rainfall. Includes woody/tree savannahs.
Tropical moist forest	Forest biome situated in areas receiving not less than 100 mm of rain in any month for two out of three years, with a mean annual temperature of $24^{o}C$ or higher; mostly low-lying, generally closed. Subdivided into tropical rain forest and tropical moist deciduous forest (ITTO, 1997).
Ultra-fine particles	Particles with aerodynamic diameters below 0.1 micrometer.
Upper respiratory symptom	Symptom in the upper respiratory tract (i.e. the respiratory tract from nose to larynx).
Values-at-risk	Any or all of the natural resources or improvements which may be jeopardised if a fire occurs (FAO, 1986; ITTO, 1997).
Visibility	Greatest distance at which a black object of suitable dimensions can be seen and recognised against the horizon sky during daylight or could be seen and recognised during the night if the general illumination were raised to the normal daylight level (WMO, 1992).
Wet deposition	Removal of pollutants from the air through the processes of wash-out, rain-out , fog, and dew
Wildfire	Any fire occurring on wildland except a fire under prescription (FAO, 1986; ITTO, 1997).
Wildland	An area in which development is essentially non-existent, except for roads, power lines, and similar transportation facilities. Structures, if any, are widely scattered and are primarily for recreation purposes (FAO, 1986; ITTO, 1997).
Wildland Fire	In contemporary thinking there are two categories of wildland fire: wildfire and prescribed fire. A wildfire is an unwanted fire and requires that measures be taken to control it. A prescribed fire is wanted, or at least serves management goals, and is thereby promoted. Escaped fire is the transitional state between prescribed fire and wildfire (FAO, 1986; ITTO, 1997).
Wildland/Residential Interface	That line, area, or zone where structures and other human development meets or intermingles with undeveloped wildland or vegetative fuels (ITTO, 1997).

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Annex D

Draft Report* from the Ad Hoc Group of Experts on the Long-range Transport and Dispersion Model Verification Database

For submission to theWMO EC Panel of Experts,
CAS Working Group on Environmental Pollution and Atmospheric Chemistry

November 10, 1998

***Disclaimer** - This draft is a preliminary version of a report being prepared for the CAS Working Group. The final report when submitted and if accepted, may or may not include changes to this version. Although this version is preliminary, it was thought that the information about the potential availability of a wide range of field experiments for the validation of long-term transport and dispersion models was sufficiently important to circulate at an early stage to WMO, WHO, and associated organizations to solicit comments and identify sources of funding. For more information please contact:

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1. Background

The recent meeting of the World Meteorological Organization (WMO) Commission for Atmospheric Sciences (CAS - XII) emphasized the importance of the coordinating role of WMO in emergency response activities and the increasing number of models to address the long-range transport of pollutants. The Commission decided there was a need to create a database of all known field experiments and the corresponding meteorological data in a common format that could then be used for model verification and development. The USA and Australia agreed to assemble a small expert group to consider the tasks required to address this issue and report their results to the CAS Working Group on Environmental Pollution and Atmospheric Chemistry.

2. Introduction

The long-range transport of pollutants in the atmosphere has received considerable attention in recent years, corresponding with a comparable number of models to address these issues. In particular there has been consistent emphasis on nuclear reactor accidents since Chernobyl by the International Atomic Energy Agency (IAEA) and the World Meteorological Organization (WMO) through the organization of WMO Regional Specialized Meteorological Centres (RSMCs). There are now 8 of these centres (Toulouse, Bracknell, Montreal, Washington, Melbourne, Tokyo, Beijing, and Moscow), each with their own modelling capabilities. The European Tracer Experiment (ETEX) symposium evaluated 47 different models. The recent ratification of the Comprehensive Test Ban Treaty (CTBT) will require the use of atmospheric dispersion models to attribute measured air concentrations to a particular source location. There is the potential for the development of a whole new class of models to deal just with this issue. The introduction of more fuel efficient jet aircraft engines (running at higher temperatures) has made modern commercial aircraft very sensitive to volcanic ash from eruptions. Centres for the modelling of volcanic ash dispersion are currently being organized through the International Civil Aviation Organization (ICAO).

Most, if not all, atmospheric transport models (ATM) are linked to one or more operational meteorological forecast models, or a particular meteorological archive, which is then used by the ATM. The data predicted by the meteorological models are routinely evaluated and compared against common performance standards. Although similar verification standards exist for the ATMs, there is a sense in the dispersion modelling community that there is very little data available to perform these evaluations. Perhaps because these data are not as easily obtained and are usually limited to single events or controlled (and expensive) field experiments that are not available on a routine basis. However there are many isolated experiments, some of which are controlled tracer releases and others from the sampling of tracers of opportunity. The problem with many of these data sets is that some are now decades old, reports are difficult to locate, if available the data are in various formats, and not all experiments archived the corresponding meteorological data.

The recent completion of meteorological re-analysis projects at several international meteorological centers provides an opportunity to link high quality modern meteorological data with each of these dispersion experiment data sets. The concept would be to create a set of CD ROMS, containing experimental data, relevant reports, meteorological data, and statistical analysis and display software, all in a common non-proprietary form. This new common database would permit the modelling community to conduct sensitivity and verification studies with considerable less preparation and effort than is now required. In addition, each modelling center or research group could produce results for each experiment that then could be compared with results from all other groups through participation in a model verification symposium.

The objectives of this report are to suggest some common standards for the data archive, review which experimental data should be included, develop a list of common model performance measures that could be incorporated in the database, and estimate the costs to complete this effort, suggest potential contractors or research laboratories that might do the work, and perhaps identify potential sources of funding.

3. Data Standards

There are three primary data sources of interest:

1) information about the pollutant release;
2) meteorological data used to calculate the pollutant transport and dispersion; and
3) measured pollutant values that can be compared with model results.

Each of these should be in a common format so that any experiment simulation can be quickly setup and results produced. Depending upon the type of experiment, information or measurements provided, there should be certain minimum requirements for an experiment's inclusion into the database.

3.1 Meteorological

It is important that the meteorological data used for all dispersion experiments is not only in a common format, but from a common source. The most easily obtained common source of gridded fields would be from one of the existing meteorological re-analysis projects. A re-analysis involves the recovery of land surface, ship, rawinsonde, pibal, aircraft, satellite and other data, quality controlling and assimilating these data with a data assimilation system which is kept unchanged over the re-analysis period, eliminating jumps associated with changes in the data assimilation system and then running the meteorological forecast model to produce the time series of gridded meteorological fields.

If a dispersion experiment had archived special observations, these could be included in the master database. Only a limited subset of the re-analysis data, sufficient for the required computations, should be included with each dispersion experiment. This is in part to limit the data volume, and in part to insure that it would be possible to reach agreements with the meteorological centers to provide the data without restrictions. If researchers require access to the complete data set, it would still be available from the original center. One may presume that these gridded meteorological fields are only one version of 'truth' and subsequently may be modified or pre-processed to support various research or modelling studies. However, it should be the best that can be done with the thoroughness of the re-analysis procedures and within the budgetary constraints of the database project.

Once it is established which experiments are to be included then an accurate estimate of data volume can be obtained. However for planning purposes let us assume that the NCEP (NOAA)/NCAR re-analysis data will be used. The fields are available on a Gaussian grid (2.5 degree) on 28 sigma levels. If all the state variables (5) are archived at all model levels, and packed in Grib format (assume 2 bytes per data point), at 4 output fields per day, the space requirements are on the order of 12 Mb per day - or only 50 days per CD. Because some of the dispersion experiments span several months, it is clear that a sub-grid corresponding to the experimental domain is required to reduce data volume. The largest reasonable domain would be a quarter hemisphere (90^o latitude, 90^o longitude), which reduces meteorological data requirements to about 1 MB per day. If experimental domains are further restricted to 1500 km domain, then data volumes shrink to 10 Kb per day. In any event, the re-analysis data will have to be processed, i.e. unpacked, the experimental domain extracted, and re-packed. Some remaining questions that can be resolved during the preparation of the final proposal are should the extracted meteorological data be in Grib, NetCDf, or perhaps some other format?

Some experiments (e.g. ETEX, CAPTEX, and perhaps a few others) may require a resolution much finer than 2.5 deg to properly capture the mesoscale effects noted by researchers working with these data. Typically one would expect those resolutions to be on the order of 1 deg and hence the costs associated with the additional factor of 6 data volume would need to be addressed in the final proposal details.

3.1.1 NCEP/NCAR re-analysis project (1958 - 1997)

The NCEP/NCAR Re-analysis Project is a joint project between the National Centers for Environmental Prediction (NCEP, formerly "NMC") and the National Center for

Atmospheric Research (NCAR). The goal of this joint effort was to produce new atmospheric analyses using historical data and analyses of the current atmospheric state (Climate Data Assimilation System, CDAS). Although the output is not under a copyright, there are nominal fees to copy the data to tape from the archives at NCAR (Boulder CO, USA) and CDC (Boulder CO, USA). The data assimilation and the model used are identical to the global system implemented operationally at NCEP on 11 January 1995, except that the horizontal resolution is T62 (about 210 km). The database has been enhanced with many sources of observations not available in real time for operations, provided by different countries and organizations. Reference: Kalnay et al., Bull AMS, 1996, 77, 437-471 and see http://wesley.wwb.noaa.gov/reanlysis.html

3.1.2 ECMWF re-analysis project

The ECMWF Re-analysis (ERA) Archive contains global analyses and short range forecasts of all relevant weather parameters, beginning with 1979, the year of the First GARP Global Experiment (FGGE). ECMWF Data Services can provide information about which years are currently available. The full model resolution for ERA is Spectral T106 , Gaussian N80 (approximately equivalent to latitude/longitude 1.125 degrees), with 31 hybrid model levels in the vertical. Additionally, the upper air data are available on 17 pressure levels. All data are written in the international standard GRIB format. ECMWF does have copyright restrictions and significant data access costs. Further it is not clear if suitable arrangements can be negotiated to provide a subset of their data without distribution restrictions. Reference: http://www.ecmwf.int/data/era.html

3.1.3 Other meteorological data.

The Data Assimilation Office (DAO) at NASA's Goddard Space Flight Center (Maryland, USA) is currently producing a multi-year gridded global atmospheric data set for use in climate research, including tropospheric chemistry applications. The data, which are being made available to the scientific community, are well-suited for climate research since they are produced by a fixed assimilation system designed to minimize the spin-up in the hydrological cycle. This assimilation produces 2 x 2.5 latitude longitude by 20 level gridded data at 6 and 3 hour intervals. Data include upper air heights, winds, temperature, and moisture as well as numerous derived quantities such as radiative heating, precipitation, ground wetness, etc. Reference: Schubert et al, 1993, Bull. Amer.Meteor.Soc., 74, 2331-2342. See http://hera.gsfc.nasa.gov/experiments/assim54A.html

3.2 Source emissions

Each experiment should include at a minimum, the location (decimal degrees) and height of the release, the amount pollutant released (kg) as a function of time (UTC). Some accidental events (such as volcanic eruptions) may have very little documented information about the release except the initial time and location, however these events may still provide valuable model performance statistics, with regard to pollutant transport directions, if not quantitative estimates of the concentrations. Other source details, if applicable, should include the nature and species of the tracer or pollutant, whether it is passive, soluble, its half-life, and if available, information on atmospheric ambient background levels. If emission amounts are known as a function of time, this information can be provided in a simple ASCII file, with each record corresponding to a known emission period, with information about the starting time, ending time, height, and amount. All fields should be space delimited, so that they can easily be used in other programs or spreadsheet applications.

3.3 Sampling Information

Pollutant sampling can be an instantaneous snapshot, such as a satellite photo, or represent temporal averages, at a fixed location, or a spatial average, such as a sample collected on an aircraft. Distinct sample collection, regardless of platform, shares some of the same data characteristics (height, location, time, duration, etc.), while satellite photos, are a rather unique product for model verification, and may be associated with some subjectivity in their interpretation due the different kind of information that may be extracted from the data. There are bound to be problems in this area.

Although consistency is very important, it remains to be seen whether it is 100 per cent achievable. Standards need to be established as to when zeroes are to be regarded as significant and included in the archive. Some experiments may report as much as 80-90 per cent of the observations as zero if they are away from the center of the plume. Missing information must be distinguished from zero readings.

3.3.1 Fixed or mobile platform samples

To maintain a certain consistency in data format between sampling platforms, although at a cost of redundancy, each sample should be identified on a unique record which contains date, time, location, height, concentration data. In this way both fixed ground-level sampling locations and samples collected on aircraft can be merged into a single database structure.

3.3.2 Satellite photos

There are several problems associated with using satellite photos: retrieval from archives, multiple channels, large data volume per photograph, and quantitative interpretation of the pollutant cloud dimensions. All the images should be converted to a standard geographic projection that can easily be matched to model output. In general these data would only be used for verification of volcanic eruptions and smoke from large scale fires. There are still many uncertainties associated with the use of these data. For instance, how the model outputs be quantified and compared with the images, how the models define the edge of the image, and should the satellite images be processed and only vectors defining the plume be saved to the archive? It is not clear that sufficient consensus exists to create a uniform database from these images. Although it is tempting to dismiss the satellite archive as too complicated to deal with in the initial phases of such a project, the sheer number of different events that could be simulated and the uniqueness and relevance of the data to the aviation industry, suggest that perhaps a corresponding verification development using the satellite archives should be considered. New satellite coming on-line will provide more quantitative aerosol measurements and could provide sufficient complementary information to properly utilize the older archives.

3.3.3 Non-conventional

For some reported experiments only derived data may be available such as plume widths as a function of distance, rather than air concentrations. Other data may include deposition, which may have been derived from many different measurement methods and over different accumulation periods at each location. These experiments will have to be evaluated on a case-to-case basis to determine their suitability for inclusion in the larger archive.

4. Potential Experimental Databases

Only experiments in which the transport distances from source to the majority of the samplers are in excess of 200 km should be considered for inclusion into the database. This is the range at which there is a transition from the Planetary Boundary Layers control of dispersion to the larger-scale 2-D synoptic influence on dispersion. Although many long-range transport models are being successfully extended to meso-scales, and therefore it may be worth thinking of a similar meso-scale verification database in the future, it would no doubt need substantial extra work due to the greater number of experiments at those scales. A similar database for very short-range experiments is being constructed by H. Olesen at RISO for short ranges (such as Kincaid, Copenhagen, Lillestrom and Indianapolis). As this proposal moves forward to the design stage, the two schemes should be mutually referenced and certainly would benefit from each other□ development in terms of data standards, statistical methods, and literature reviews.

It is necessary to establish guidelines for which type of data should be included in such an archive. In general there are three types of experiments:

1) controlled experiments in which the pollutant release rate is known,
2) accidental ones in which it is unknown (and never will be), such as volcanic eruptions, and
3) pure transport experiments, such as balloon releases.

The controlled group would include such events as the Chernobyl accident, in which the source term was reconstructed after the fact. Controlled experiments provide quantitative concentration or deposition data, however in general one will find that each experiment has different limitations, usually related to how many samples could be analyzed. Experiments with detailed spatial and temporal resolution are usually limited to a few cases. Experiments that cover many events usually have either low spatial or temporal sampling resolution. Each experiment may serve a different model verification or development purpose. Accidental uncontrolled releases, such as volcanic eruptions, may have little or no quantitative sampling data, but yet may be rich in temporal history of satellite photographic images of plume positions.

An abstract of potential experiments, familiar to the working group members, follows below, each with known references and availability of data. There are probably a considerable number of other experiments, less familiar to this group, that should also be reviewed. The initial stages of the database design should include a comprehensive literature search, the results of which should be included in the database regardless of whether the individual experiments have been included.

4.1 Controlled Field Experiments

4.1.1 USA, Idaho, Kr-85, 1974

Three months of Kr-85 releases from Idaho and continuous 12 h sampling at 13 locations in a line about 1500 km downwind. Limitations: many samples near background and background variability comparable to signal. Advantage: continuous time series does show a few distinct plumes and unique in that transport was across the Rocky Mountains. Data available: only in publication. Reference: Atm. Environ., 1982, 16: 2763-2776.

4.1.2 USA, Oklahoma, PFT, 1980

A single release perfluorocarbon (PFT) tracer over a 3 hour duration with samples of 3 hour duration collected at about 40 sites 600 km downwind from the release. An additional Heavy Methane (HM: $^{12}CD_4$ and $^{13}CD_4$) tracer released simultaneously with the PFC was measured at 3 locations up to 2000 km downwind. Limitations: single event with release in pre-defined conditions. Advantage: Detailed temporal and spatial history as plume passes 600 km sampling arc under rather unique conditions of nocturnal jet and secondary tracer maximum. Data available: only in publication. Reference PFC: Tech. Report EPA-600 copy at:

ftp://www.arl.noaa.gov/pub/tracer/captex.

Reference HM: M.M. Fowler and S. Barr, 1983, Atm. Environ., 17:1677-1685.

4.1.3 USA, CAPTEX, PFT, September - October 1983

Cross Appalachian Tracer Experiment consisted of six 3 h PFT releases, all independent of each other, four from Dayton, Ohio and two from Sudbury, Ont, Canada with samples collected about 80 sites, 300 to 800 km from the source, generally at 6 h averages for 48 hours with each release. Advantages: extensive multiple aircraft samples available for many of the releases at various downwind distances. Data available: ftp://www.arl.noaa.gov/pub/tracer/captex. Reference: NOAA Tech Memo ERL ARL-142.

4.1.4 Ukraine, Chernobyl Accident, April 1986

A 10 day release with extensive air concentration and deposition measurements. Limitations: still some controversy regarding the reconstructed emissions and there is limited information on daily wet deposition of Cs-137. Advantage: the only data with extensive measurements of air concentrations and radioactive wet and dry accumulated deposition with much more data available now than at the time most initial studies were published. Data available: Cs-137 and I-131 air concentrations, and Cs-137 daily and accumulated deposition from the REM data bank at JRC Ispra at http://java.ei.jrc.it/. Reference: Klug et al., Evaluation of long-range atmospheric models using environmental radioactivity data from the Chernobyl accident, EUR 14148 EN, Elsevier, 1992,ISBN 1-85166-766-0.

4.1.5 USA, ANATEX, PFT, January - March, 1987

The Across North America Tracer Experiment consisted of 66 PFT releases (33 each from two different locations) every two and one half days. Air samples were collected over 24 h periods at about 60 sites covering most of the eastern US and southeastern Canada. Aircraft sampling limited to within a few hundred kilometers from the sources. Limitation: temporal and spatial resolution is poor. Advantage: many distinct tracer plumes move through the sampling network under a variety of different meteorological conditions. Data available: ftp://www.arl.noaa.gov/pub/tracer/anatex. Reference: NOAA Tech Memos ERL ARL-165, 167, 175, and 177.

4.1.6 USA, Southwest - Mohave, PFT, 1992

Continuous releases for two one month periods, summer winter, daily sampling at a variety of locations in complex terrain over several hundred kilometer domain. Data available: ftp://eafs.sage.dri.edu/currproj/mohave
References: contact Mark Green (green@snsc.dri.edu)

4.1.7 *Europe, ETEX, PFT, 1994*

Two releases of PFT with 3 h sampling at 167 locations to 2000 km from the source over a 3 day period. Limitation: only a limited number of measurements are available for the second release that occurred during a frontal passage.
Advantages: tracer measurements from aircraft are available, although they have not yet been extensively evaluated. Data available: from http://www.ei.jrc.it/etex/. References: EUR publications in progress, submitted to special issue of Atm. Environ.

4.1.8 *USA, Mid-Atlantic coast, ACURATE, Kr-85, 1982-1983*

The ACURATE experiment consisted of measuring the Krypton-85 air concentrations from emissions of the Savannah River Plant, SC, Twice-daily (12h) average air concentrations were collected for 19 months (March 1982 - September 1983) at 5 locations along the east coast of the U.S from 300 to 1000 km from the plant. Limitation: only 5 locations with frequently only one or two sites showing above background signal for any event. Advantage: the only experiment that covers all four seasons with 750 of 3858 samples showing above background signal. Data available: ftp://www.arl.noaa.gov/pub/tracer. Reference: NOAA Tech Memo. ERL ARL-130

4.1.9 Australia, Mt. Isa SO2 plume, 1979-1981

Measurements by Division of Coal and Energy Technology, CSIRO. Data available: john.carras@syd.dcet.csiro.au. References: Carras and Williams, 1981, Atm. Environ., 15:2205-2217 and 1988, Atm. Environ., 22:1061-1069.

4.1.10 England, North Sea experiment

Transport of SF6 from a South Yorkshire power station over the North Sea. References: A. S. Kallend and J. Crabtree, 'The fate of atmospheric emissions along plume trajectories over the North Sea; Final Report'. Leatherhead: Central Electricity Research Laboratories TPRD/L 2340/R82, 1983 and J. Crabtree in the 13th NATO/CCMS Conference (1982), and J. Crabtree in Air Pollution Modelling and its Applications III, Plenum Press, p. 129-138.

4.1.11 England, Windscale Accident, 1957

References: J. Crabtree, 'The travel and diffusion of the radioactive material emitted during the Windscale accident', Q. J. Roy. Met. Soc., 85(362), 1959; A.C. Chamberlain, 'Deposition of iodine-131 in Northern England in October 1957',Q. J. Roy. Met. Soc., 85(350), 1959; J. Gray et al., 'Discharges to the environment from the Sellafield site 1951-1992', J. Rad. Prot., 15(2), 1995.

4.1.12 *Europe, TRACT-TRANSALP experiments, 1989-1992*

TRACT relates to mesoscale transport of pollutants to distances of 100's of kilometers. TRANSALP consisted of three campaigns in the middle of the Alps. Only in the third (1991) of the TRANSALP experiments, tracer (PFC) was released from the northern edge of Lake Lucerne and measured over distances larger than 100 km to Lake Maggiore in Italy. In the other two campaigns (1989, 1990) the range of distances was considerably lower (40 km). Aircraft measurements were also performed. Data available: Data bank of the experiment is available at JRC Ispra by request from Dr. G. Graziani (giovanni.graziani@jrc.it). Reference: Special Issue on Transport of Air Pollutants over Complex Terrain (TRACT), Atm. Environ., Vol. 32, April 1988, pp 1141-1352.

4.1.13 Europe, the Oeresund Experiment, 15 May - 14 June, 1984

Nine tracer experiments were performed during the campaign. In each of them, the tracer (SF6) was released close to the upwind coastline and sampled in the Oeresund, at the downwind coastline and further inland. Data availability: data-bank of the experiment is available at Risoe, Dr.S.E. Gryning, sven-erik.gryning@risoe.dk. Reference: The Oeresund Experiment Data bank, ISBN 87-550-1592-1

4.1.14 Antarctic, June and October 1984

Four releases (January, June, and October) from aircraft of heavy methane and 3 day sampling at 8 ground-level locations up to 60 days after the release. Some limited aircraft sampling during the period. Advantage: transport and dispersion in a unique environment in both winter and summer. Limitation: not all samples were analyzed, to reduce experimental cost. Data: supplemental data tables on microfiche from AGU. Reference: E.J. Mroz et al., 1989, J. Geophys. Res., 94(D6)8577-8583.

4.2 Uncontrolled Releases (generally only satellite data available)

There are perhaps more questions than answers with regard to these events. Bushfires and volcanic eruptions certainly need to be treated differently. Emission heights need to be estimated from the satellite archives. It is important to distinguish between cloud and ash. Different events will have different lifetimes, the time during which a clear distinction can be made of the plume from the background. Picture resolution will depend on whether the event occurs during the day where the higher resolution VIS images are available or at night when infrared is available. IR images may have to be processed to obtain brightness temperatures and thus approximate release height. The frequency at which the images are to be archived (to reduce storage requirements) should be determined from the temporal evolution of the plume.

4.2.1 USA, Mt St. Helens eruption, 1979

Extensive satellite and ground observations were made during the event. References: Satellite images of the Mount St. Helens cloud can be found at Holasek and Self (1995) GOES weather satellite observations and measurements of the May 18, 1980, Mt. St. Helens eruption, Journal of Geophysical Research 100: 8469-8487, http://www.geo.mtu.edu/eos/ppages/self.html(*); also J. Crabtree and M. Kitchen, Atm. Environ., Vol. 18, No. 6, 1984.

4.2.2 Philippines, Mt. Pinatubo eruption, 1991

References: Holasek RE, S Self, and AW Woods (1996) Satellite observations and interpretation of the 1991 Mount Pinatubo eruption plumes. J. Geophys. Res. 101: 27635-27655.

4.2.3 Kuwait, Oil Fire smoke plume, 1991

Reference: J.T. McQueen and R.R. Draxler, 1994, Atm. Environ., 28:2159-2174; K.A. Browning et al., Nature, May 1991, 351, 363-367.

4.2.4 Recent Events

Some of the more recent events have not yet been well documented in the literature, but certainly images could be retrieved from satellite archives. These could include events such as the Papua New Guinea Rabual eruption (1994), the New Zealand Ruapehu eruption (1996), bushfire smoke from Kalimantan, Sumatra, Irian Jaya, Papua New Guinea (1997), and the China Dust Cloud (April, 1998).

4.3 Other potential experimental data

Balloon flight data provide an opportunity to test only the transport component of a model, rather than both transport and dispersion. However, in addition to balloon position, the altitude must be known as well, which is usually tabulated with the controlled balloon experiments for various research projects such as the ACE-1 experiment near Tasmania in 1994 (J. Geophys. Res., 1988, 103:16,297-16,758), the Smith/Kavanagh balloon trajectories over Australia in 1993 (Mills et al., 1994, Aust. Met. Mag., 43:29-39), the February 1995 Fossett trans-Pacific manned flight (Weather and Forecasting, 1996, 11:111-114), a European balloon race (K.Baumann and A. Stohl, 1997, J. Appl. Meteorol., 36:711-720), and some tetroon releases in the central US (W.A. Hoecker, 1977, J. Appl. Meteorol., 16:374-383). Recent manned balloon flights by Fossett over the North and South Atlantic and the recently completed ACE-2 experiment can also be added to the list when data become available. Other balloon experiments of opportunity do not always have detailed height data available such as the 190,000 small helium balloons that were released in May 1986 all over the USA, of which 8,000 were found and their final position reported (R.A. Stocker, et al., 1990, J. Appl. Meteorol. 29:53-62).

5. Data Processing Requirements

In general the space requirements of the sampling data will be small compared with the meteorological data fields that will accompany each experiment. There will be some effort required to digitize any data not already in that form and reformat those that are already in digital format. Space estimates for meteorological data (shown below) are quite modest for the low resolution fields (2.5 deg) and still reasonable for the high resolution data (1 deg), in that at least all the major tracer experiments should fit on one 640 Mb CD.

Experiment	Domain Lat x Lon	Period Days	Low-Res Mb	Hi-Res Mb
Idaho	30 x 40	90	15	60
Oklahoma	20 x 30	5	1	5
CAPTEX	15 x 25	20	1	5
ACURATE	15 x 15	570	15	75
Chernobyl	40 x 60	30	10	40
ANATEX	30 x 60	90	20	80
Mohave	10 x 20	80	2	10
ETEX	30 x 40	5	1	5
Total			65	275

The effect of the addition of satellite data to the archive is uncertain, but the addition of one or more CDS would not diminish is practical applications. The greatest cost of the satellite data would be the processing required to standardize the images.

6. Statistical Analysis and Display Software

The statistical package could be included in two versions, one that may be based on a common proprietary software that might already be available to many researchers (e.g. IDL, SAS, NCAR graphics, etc.) and which would include some graphical routines as well and a non-proprietary version which will allow modelers to analyze and display their results in a common format to facilitate inter-model comparisons. These could be pre-compiled programs for Windows PCS or □C or Fortran source code that could be compiled on Unix workstations. Recent developments in statistical model comparisons, in particular the ETEX data, demonstrated how model evaluations could be taken beyond the time and station paired methods to temporal and spatial pattern matching approaches.

7. Work Plan Guidelines

At this point it is uncertain where and how the work to develop the database should be accomplished. It is possible to estimate the costs required to complete the database. Perhaps an existing government, research laboratory, or contractor, could be enlisted. Scientific oversight is required. In general the tasks are summarized below with a gross estimate of the man-months effort for each component, some of which could be completed concurrently.

7.1 Creation of the final work plan by the project team

This would include the results of a comprehensive literature search for suitable experiments, the final technical specifications, and element should be harmonized with budget. Effort: 3 months.

7.2 Development of a standard electronic format

This will encompass all the different experimental data with specific application programs for each experimental data set to create a common format product. If digital copies of the data are not available it will be necessary transcribe published results to electronic form. Effort: 6 months.

7.3 Meteorological data

Meteorological data that corresponds to the spatial domain and period of the experiment should be obtained from one of the re-analysis projects and extracted, and re-packed into a common format for all experiments. Effort: 6 months.

7.4 Satellite data

The satellite data will provide images primarily for qualitative verification at this stage. With the launch of POLDER, TOMS, OCTS, MODIS, and MISR instrumentation, quantitative verification of aerosol transport and dispersion may soon be possible. However there should be at least 3 images per event and it would include both VIS for higher resolution (when possible) and IR for temperatures. Resolution should be sufficient to extract plume position information but with a conscious effort to conserve storage volume. Effort: 9 months.

7.5 Guidelines

Provide guidelines for model developers to also output their results in a standardized format. Rewrite existing statistical analysis and display software to access both Experimental and model data and provide software either as an executable that can be run on a common platform (i.e. Windows PC) or provide code (□C□ or Fortran) that could be compiled and run at each of the modelling centers. Effort: 6 months.

7.6 Copies of CD

Arrange for multiple copies of the CD and distribution to a wide audience, perhaps in conjunction with an article in a major international journal. WMO would sponsor a model verification symposium inviting participation through the journal article. Effort: 6 months.

8. Funding Sources

This report, with the recommendations of the CAS Working Group on Environmental Pollution and Atmospheric Chemistry, should be distributed by WMO to the IAEA, ICAO, and other national and international agencies interested in long-range pollutant transport. As part of the issue regarding finding sources of funding it is necessary to identify who will actually do the work. This may simplify the funding uncertainty. For instance, financing could be sought in the next Cost-Shared-Actions programme of EC DG XII (Environment and Climate) that starts next year. Perhaps if one major funding source were identified, others would be more willing to contribute toward to the project’s completion.

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Annex E

ITTO GUIDELINES ON FIRE MANAGEMENT IN TROPICAL FORESTS

Pursuant to Decision 1 (XI) of the International Tropical Timber Council (ITTC), an Expert Panel was established to develop Guidelines for the Protection of Tropical Forests Against Fire. An Expert Panel met in Jakarta from 6-10 March 1995 to prepare the draft guidelines on the base of a document prepared by J. Goldammer (Germany) and S. Manan (Indonesia). After revision of the guidelines the document was approved by the ITTC at its 21st Session held in Yokohama, November 1996.

The ITTO guidelines are considered a major cross-reference and source document which addresses the fire and smoke problems at the source. The original guidelines document which contains several Annexes is published by the ITTO:

> International Tropical Timber Organization (ITTO) 1997. ITTO Guidelines on Fire Management in Tropical Forests. ITTO Policy Development Series No.6. ITTO, Yokohama, 40 p.

Copies can be obtained from the ITTO Secretariat:

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1. INTRODUCTION

The vast majority of today's global vegetation fires are human-caused, and take place in the tropics and subtropics. They are the result of the increasing human population pressure on these areas where fire is being used extensively as a land treatment tool, e.g., for conversion of forested lands into agricultural lands; for maintaining grazing lands; and for facilitating the utilization of non-wood forest products of the seasonal forests and savannas.

In the evolutionary history of the seasonal tropics, lightning fires have significantly contributed to shape savanna and forest ecosystems. In addition, fire influence through traditional burning practices over millennia has strongly favored and selected plant communities that are considered to be sustainable and long-term stable fire ecosystems. However, the contemporarily changing fire regimes, and the alteration of sustainable time-space-fire relationships in the wake of changing land-use practices are often associated with forest and site degradation.

Tropical rain forests can be severely affected by fire. Shortening of shifting cultivation cycles and the increasing occurrence of escaping land-use fires into tropical rain forests cause high ecological damage by reducing biodiversity. Fire-induced loss of soil cover negatively affects hydrological regimes and soil properties, leading to severe erosion and loss of productive topsoil. High economic losses are caused by damaging valuable timber and non-timber resources, natural regeneration, and planted forests.

In addition, burning of forests and other vegetation of the tropics may exert impacts at different levels on local, regional, and global environments. Smoke from large scale tropical fires also reduces safety of air, land and coastal marine traffic; and may cause problems to human health. Fires in the interface of wildlands and residential areas often cause the loss of human lives, property, and other values at risk, e.g., forestry enterprises, sawmills, power lines, other infrastructures, and livelihoods.

On the other hand, fires play a central role in the maintenance of many natural ecosystems, as well as in the practice of agriculture and pastoralism. Tropical moist savannas in many regions are maintained by fire and would return to seasonal tropical forests if fire could be excluded. Some seasonal tropical forests regularly affected by fire produce valuable timber and non-wood forest products.

These ***ITTO Guidelines on Fire Management in Tropical Forests*** build on the previously published *ITTO Guidelines on Sustainable Management of Natural Tropical Forests, the Establishment and Sustainable Management of Planted Tropical Forests, and the Conservation of Biological Diversity in Tropical Production Forests*.

These fire management guidelines are designed to provide a base for policy makers and managers at various levels to develop programs and projects in which the specific national, socio-economic, and natural problems related to fire in tropical natural and planted forests will be addressed. The scope of the guidelines is to assist the ITTO producer and consumer countries to develop programs for reducing damage caused by fire; and to help tropical forest managers and rural residents to safely use and take advantage of the beneficial effects of fire in land-use systems. The Guidelines are in accordance with the UN Resolution 44/236 in which the 1990's were designated as the International Decade on Natural Disaster Reduction (IDNDR). One objective of IDNDR is to reduce damage, economic disruption, and loss of life caused by wildfires through concerted international action, especially in developing countries.

The Guidelines recognize that many forest fires originate in the agricultural and pastoral systems; and in degraded vegetation which is outside of forests. Therefore, fire management on former and degraded forest lands may help to re-establish productive forests and to safeguard the success of reforestation programs.

2. POLICY AND LEGISLATION

POLICY DEVELOPMENT

Principle 1

The successful implementation of a policy to protect tropical forests against fire is highly dependent upon broad-based support from all sectors of society, particularly civic organizations and groups working with the responsible government authorities on a voluntary basis, and must be supported by appropriate legislation which is in harmony with laws concerning related issues.

Recommended Action 1

a. Identify local communities, concession holders, timber companies, contractors, conservation non-governmental organizations (NGOs), women's groups, and other voluntary organizations to assess their interest and capacity to forge partnerships with government authorities in fire management programs. Where necessary, assistance will be provided by government authorities in the development of such organizations.

b. A national fire policy forming an integral part of the national land use policy, and assuring sustainable forest management, should be formulated and accepted by all relevant parties, including government, local communities, and the private sector.

c. Establish, and effectively staff and fund, a decentralized national agency, or strengthen an existing institution responsible for the establishment and implementation of an effective fire policy.

d. Enact and/or revise national and local laws and regulations regarding the proper use of fire to ensure the effective implementation of fire management policies.

e. Create a system of incentives and sanctions which will encourage responsible use of fire at all levels, including timber felling and saw-milling.

Principle 2

National parks, national forests, and equivalent reserves protect important and unique representative samples of tropical forest ecosystems as part of the world's natural heritage. These conservation units can be damaged by wildfires, which are usually caused by the activities of rural populations.

Recommended Action 2

a. In a national system for fire management, the protection of conservation areas should be considered a priority.

b. Develop fire protection plans for forest lands with high conservation values.

3. STRATEGIES

FIRE MANAGEMENT PLANNING

Principle 3

A fire management plan is an essential component for the prevention, suppression, and management of fire within forests and adjacent lands. Fire management plans must be part of an overall land-use (e.g. forestry) management plan. Planning should be on a cooperative basis on national, regional, provincial, and local levels as appropriate.

Recommended Action 3

a. Provide adequate resources for fire management planning at different levels of fire activity.

b. Develop fire management plans, which include a clear statement of objectives; and incorporate information on land tenure, assets threatened, degree of fire risk, fire history, and fire management measures.

c. Promote the active participation of concession holders, timber companies, contractors, local communities, and all other voluntary organizations, particularly non-governmental and women's groups. Their participation needs to be based on their abilities which could be enhanced through training in fire management; and on providing appropriate equipment and incentives whenever feasible.

FIRE MANAGEMENT OPTIONS

Principle 4

The selection and application of fire management options depend upon the conditions and circumstances found at the national, provincial, and local levels which may include, *inter alia*:

- Forest types and management activities,
- Risk and sources of fire,
- Access and terrain,
- Fire management capabilities,
- Climatic conditions,
- Adjoining land uses, and
- Socio-economic factors.

Recommended Action 4

a. Select and develop the appropriate fire management option which takes into account local circumstances and conditions.

b. An integrated fire management programme should be developed which may include some or all of the following fire management measures:

- Community participation in fire protection,
- Fire prevention (e.g. fire breaks, fuel breaks, and fuel management),
- Fire pre-suppression (e.g. collection of fire intelligence, weather and fire danger forecasts, detection and early warning and reporting systems, fuel assessment, equipment, communications, water supplies, and training of fire fighters, etc.),
- Prescribed burning (e.g. fuel reduction, slash burning, etc.),
- Fire suppression,
- Law enforcement and incentive systems,
- Training, extension and public awareness programs, and
- A compost processing policy for agricultural waste or residues from other operations carried out near forest areas.

Principle 5

Fire detection and early warning systems are essential for the rapid and effective control of wildfires. A wide range of fire detection options exists, including look-out towers, surveillance aircraft, ground patrols, satellites, and information provided by the general public.

Recommended Action 5

a. Explore and seek access to all potential sources of information and communication of early fire detection.

b. Develop a system of early and rapid dispatch to fires, including assessment of likely routes of travel to determine impediments.

FIRE SUPPRESSION

Principle 6

Typical fire situations in many tropical vegetation types can be successfully controlled and managed by experienced ground crews of fire-fighters. The success of ground crews depends upon local fire organization, on the availability of adequately designed hand tools, and the provision of basic training in fire suppression and fire fighter's safety. Fire fighting equipment is available in developed countries and may be adaptable to tropical forest conditions.

Recommended Action 6

a. Encourage the formation of volunteer fire fighting brigades from local communities and forest users.

b. Provide local brigades with well-constructed fire fighting tools and basic equipment.

c. Provide training on fire fighting techniques and tactics to brigade leaders and fire crews; introducing technologies to enable fire organizations to combat forest fires. Such provisions may be possible through support from forest management organizations.

Principle 7

National level emergencies can occur involving numerous large fires due to changing climatic conditions, which exceed local and provincial capabilities. Disasters may be avoided if sufficient action is taken at an early stage.

Recommended Action 7

a. A national fire fighting contingency plan which involves relevant government agencies, other organizations, and local communities should be set up to deal with large scale emergencies. This plan should outline the responsibilities of the various parties involved to prevent duplication of efforts and to optimize human and financial resources. Consideration should be given to the recruitment of international support where appropriate. Arrangements on financial components must be agreed to well before emergencies arise.

ROLE OF COMMUNITIES IN FIRE PROTECTION

Principle 8

The majority of tropical forest fires and other wildland fires are caused by the activities of the rural population. An efficient fire prevention strategy therefore requires an initial understanding of the cultural and socio-economic background of the tropical fire scene. The fire prevention programme relies heavily on a positive relationship between the rural community and the forest-fire manager. Mutual confidence and public support can be created by participatory approaches.

Recommended Action 8

a. Employ or encourage participation of rural residents in fire prevention work, such as establishment and maintenance of fire breaks and other fuel treatments.

b. Encourage integration of agriculture and grazing land-use into fuel break systems through incentive mechanisms (e.g. through cost-free leasing of fuel break lands). Where burning is used as a form of pasture health management, incorporate techniques to minimize risk of escaped fires.

c. Stimulate community cooperation in fire prevention through various incentive measures such as provision of funding popular initiatives for villages which have succeeded in preventing the spread of wildfires into adjoining forest lands. For example, systems to supply potable water are often lacking in some remote areas; and installation priorities are often uncertain. A community which demonstrates major reduction in harmful fires could be rewarded by having its system installed more quickly.

4. MONITORING AND RESEARCH

MONITORING

Principle 9

Assessment, prediction, and monitoring of fire risk, as well as a means of quantification of forest fires and other rural fires are prerequisites for fire management planning purposes. Statistical data sets can also be used to gain the attention of authorities, policy makers, and the general public. In the tropics such information is difficult to gather by ground based-methods. Airborne and spaceborne sensors offer possibilities to monitor less accessible and sparsely populated land areas with inadequate ground-based infrastructures.

Recommended Action 9

a. Seek access to meteorological information from ground stations, and space borne systems; using this information for fire intelligence (fire risk assessment).

b. Use existing orbital remote sensing systems for fire detection and prediction to obtain real-time information on the geographic location of fires.

c. ITTO member countries should join others in supporting the development of international mechanisms, (early warning systems), to predict wildfires. Such a system would not predict occurrence, but rather would report the development of conditions which can be counted on to result in serious fires. It would have to gather and interpret information from a number of sources, including satellites, and land-based stations.

RESEARCH

Principle 10

Basic scientific and applied research are the fundamental sources of information needed for tropical forest fire management. Research on fire behavior and its impact on ecosystems, bio-geochemical cycles, atmospheric quality, and local and global climate, as well as evaluation of damages and losses, will help to establish indicators on how to manage fire in various tropical forest ecosystems.

Recommended Action 10

a. Support universities and research institutions, in cooperation with international partners, to undertake research on tropical forest ecosystems including the following main areas of interest:

- Compilation and explanation of the state of the art of fire knowledge on past and present fires (occurrence, and ecological impacts)
- Fuel inventory and modelling,
- Fire behavior models,

- Fire risk indicators,
- Fire risk mapping,
- Fire-weather prediction,
- Environmental impact models,
- Impacts of gaseous and particle emissions of fires on bio-geochemical cycles, atmosphere

and climate,

- Socio-economic aspects of forest fire, and
- Rehabilitation of forests damaged by fire.

b. Study the dynamics of swidden lands and secondary forests, as well as timber and non-timber products, which are used by the local communities and are likely to contribute to the cause of fires.

c. Establish demonstration modules for non-traditional harvesting of secondary forests with a view to offsetting the pressure exerted by agricultural burning practices.

d. Establish demonstration practices to offer alternatives for the preparation of agricultural lands other than the burning of felled trees.

Principle 11

Knowledge of forest fires and fire management must be exchanged among forestry and research personnel throughout the world to enhance the coordination and cooperation in forest fire prevention and suppression.

Recommended Action 11

a. Select and conduct training courses on information exchange methods, such as Internet and other relevant electronic communication systems.

b. Promote periodical international seminars on forest fire management.

5. INSTITUTIONAL FRAMEWORK AND CAPACITY DEVELOPMENT

INSTITUTIONAL DEVELOPMENT

Principle 12

Institutional development and strengthening are highly critical, and attention should be given to human resource development. Fire management must be implemented under the jurisdiction and responsibilities of all land owners involved, i.e. on lands managed by national and provincial governments, local communities, concession holders, timber companies, contractors, and private forestry enterprises. However, an institutional framework must ensure that the national fire policy will be implemented.

Fire management measures affect various sectors of the society, and fall within the responsibilities of a variety of government agencies and land users. Therefore, a national interagency structure must coordinate the various responsible agencies involved in order to maximize efficiency and to share fire management resources. Assistance through bilateral and international programs should be encouraged in order to enable the transfer of existing knowledge and advanced technologies where needed.

Recommended Action 12

a. Establish or strengthen structures at the national level which are responsible for preparing and implementing national fire policies. Additional governmental infrastructure should be established or strengthened to build up fire management capabilities at the provincial and local levels.

b. Develop or strengthen suitable mechanisms and structures at national, provincial, and local levels to provide for the establishment and coordination of rural fire brigade organizations, including volunteer fire brigades.

c. Develop operational plans in which the role of voluntary organizations, particularly non-governmental and women's organizations, are defined and exercises conducted at intervals to strengthen procedures, and enhance preparedness.

d. The institutions responsible for fire management should promote cooperative agreements between rural communities, NGO's, forest companies, and the relevant public institutions, as well as political authorities.

e. Nations and organizations with fire management expertise should offer advice in building institutional frameworks and capacities; to provide for technical assistance, materials, and support to countries lacking adequate infrastructure.

Principle 13

Fires may affect resources on the territories of neighboring countries; or may have transboundary effects, e.g., smoke pollution. Cooperative agreements between neighboring countries may help to solve transboundary fire problems; and allow for sharing of resources at regional scale.

Recommended Action 13

a. Establish bilateral and multilateral agreements on cooperation, and mutual assistance in fire management.

b. ITTO member countries should have mobile rural fire brigades in order to provide fire management support in situations that go beyond the capacity of the affected country. These brigades would, at the invitation of the affected country, enter that country and augment its fire fighting forces until the crisis passes.

FUNDING AND IMPLEMENTATION

Principle 14

Large fires in the tropics may adversely affect global economies, environment, and biodiversity. Timber which is destroyed or degraded lowers the supply of available forest resources, and affects prices worldwide. Cost of management of these fires should logically be borne locally, nationally, and when appropriate, internationally. To prevent and combat these fires, appropriate institutional infrastructures and mechanisms should be supported from national resources and, if necessary, international cooperation and assistance could be considered.

Recommended Action 14

a. Implementation of a programme to protect the forest against fires requires forest authorities to establish special units responsible for such a programme at national, provincial, and local levels with adequate, financing, staff, skills, equipment, and operational procedures.

b. Cooperation and active involvement of local communities, the private sector, non-governmental organizations, and the mass media must be promoted to ensure the implementation of an effective program.

c. To ensure preparedness, coordination, adequacy, and effectiveness of operational procedures, workshops, and exercises at various levels, should be organized at regular intervals involving all affected parties, including neighboring countries, as appropriate.

d. Relevant international and regional organizations should promote cooperative efforts to prevent and combat forest fires.

e. Donor countries should accord high priority in their development assistance programs to help developing tropical countries establish programs to protect forests against fires through financial assistance, provision of expertise, transfer of technology, and assistance in training.

f. Development banks should favorably consider providing assistance to developing tropical countries to protect forests against fires through the provision of grants or loans at concessionaire rates.

g. Multilateral facilities such as the GEF (Global Environmental Facility), UNDP (United Nations Development Program), the Common Fund for Commodities, and other relevant arrangements should create 'windows' to support activities related to the protection of tropical forests against fires.

h. International organizations such as the ITTO, FAO (United Nations Food and Agriculture Organization), UNEP (United Nations Environmental Program), UNDRO (United Nations Disaster Relief Organization), UNESCO (United Nations Educational, Scientific and Cultural Organization) and other relevant organizations, activities (e.g. IDNDR), and international initiatives and conventions should strengthen programs related to protection of the forests against fires. ITTO member countries should join others in supporting the development of international mechanisms to obtain prompt assistance to mitigate the consequences of wildfire disasters, upon request.

i. The CSD (United Nations Commission on Sustainable Development) should ensure that in the implementation of Agenda 21 for forests, due attention is given to forest fires in relation to arrangements that may be developed to harmonize and promote international efforts to protect the world's forests. A UN-sponsored Global Fire Research and Management Facility, which includes a Global Vegetation Fire Information System, and the capabilities to provide support on request to any nation in fire management, should be considered by the CSD.

j. Donor countries and lending institutions should ensure that their project appraisal procedures include fire risk assessment; and where appropriate, adequate resources should be included in the project budget for fire protection.

k. Seek the cooperation of NGOs, women's groups, and other voluntary organizations, to raise funds in support of programs to protect tropical forests against fire.

l. Projects and activities related to the protection of tropical forests against fire should merit support from the Bali Partnership Fund to be established under the ITTA (International Tropical Timber Agreement) of 1994.

6. SOCIO-ECONOMIC CONSIDERATIONS

ECONOMIC IMPLICATIONS

Principle 15

Damage to forest cover and the wasteful burning of biomass cause significant loss of productive resources. Forest fires also negatively affect the environment, e.g. soil and water resources, and atmospheric qualities. This has direct and indirect cost implications to the country. At the same time, programs to protect forests from wildfires are complex and costly. Many sectors of the economy, including the forestry, agriculture, fisheries, transportation, and health sectors, stand to benefit from effective fire management; and should be prepared to contribute equitably towards the costs.

Recommended Action 15

a. Estimate the potential direct and indirect costs to the national economy brought about by wildfires. The costs of various options of preventing and controlling wildfires should also be estimated to ensure that fire management policies and programs are viable.

b. The agency responsible for fire protection should undertake a cost/benefit analysis of proposed fire management programs under a variety of scenarios. It should design programs which are cost effective and within its budgetary means. National and provincial governments should be prepared to provide adequate financial support to the forestry agencies should it be necessary for them to meet costs.

Principle 16

Preventing wildfires is much more cost-effective than suppressing them and bearing the resulting losses. The causes of forest fires, and the underlying reasons for them, need to be determined before effective prevention plans can be made. The general public can be an important cause of wildfire. One reason for this is a lack of understanding on the importance and value of forests. In many tropical countries, uncontrolled shifting cultivation (slash-and-burn, swidden system) is a source of wildfires, as is the use of fire to dispose of crop residue and woody vegetation during land conversion.

Recommended Action 16

a. Promote improved agricultural and agrosilvopastoral systems as alternatives to shifting cultivation.

b. Establish model demonstration areas for specific farming and agrosilvopastoral practices, combining them with other components of a fire management system (e.g. integrating farming and grazing activities to modify fuel loads or fuel break systems).

c. Develop suitable incentive programs to reward communities and individuals which use appropriate land-use practices, resulting in reduced fire damage. In the case of individuals, it is often effective to simply make formal recognition , in the presence of peers, that the individual has done something special.

d. Develop and promote an environmental awareness programme on the relation between social, economic, and environmental benefits derived from forests, and the negative impacts associated with wildfires.

e. Establish a programme to investigate the causes of wildfires, and the underlying reasons. This should form the basis for formulating a wildfire prevention, education, and extension program.

f. Develop and implement programs following the principles of regenerative agriculture to promote nutrient cycling so that biomass is utilized to enhance soil fertility. These programs should consider sustainable agricultural practices promoted and disseminated by organizations such as the IIRR (International Institute for Rural Reconstruction), CATIE (Center for Research and Training in Tropical Agriculture), and grassroots level NGOs.

g. Demonstrate a variety of land treatment and soil preparation practices which apply viable and inexpensive soil and water conservation techniques. Consider establishing demonstration plots where fire is not utilized as a tool in site preparation or land clearing.

COMMUNITY CONSULTATION

Principle 17

There may be competing or conflicting land resource uses between rural inhabitants and other land use classifications such as forest concessions, timber companies, contractors, and conservation units. These conflicts can lead to the setting of wildfires. People need to be able to benefit directly from forest uses in order to value and protect these resources. Local people use fire for economic, religious, agricultural, and cultural reasons; and they will continue to do so in the future. Experiences gained from traditional fire management practices may be of benefit within a wider national context. Some tropical countries have experience with fire management involving local communities, with varying degrees of success. Lessons from these experiences may be beneficial to other countries.

Recommended Action 17

a. Provision should be made for consultations with people within communities in an open and transparent way to resolve conflicts on rights of forest land use and the obligation of fire protection.

b. Local people should be trained in techniques to manage and control fire so as to prevent destruction of the forest cover; taking into account their traditions and skills.

c. Local governments and citizens should be involved in decisions on how fire will be managed in areas under their purview. Communities may also need financial assistance to carry out fire prevention measures and respond to wildfires. Community organization and training must be done following participatory methodologies in order for them to be effective and sustainable.

d. Provide opportunities for exchange of information and experiences in fire management involving local communities through forums supported by international organizations such as ITTO, FAO, CIFOR (Center for International Forestry Research), and multi-lateral mechanisms.

Principle 18

In many rural societies, women play an extremely important role in agriculture, raising livestock, collecting fuel wood, and utilizing the forest to produce non-timber goods. Women are therefore more appreciative and caring for the natural environment although it is often difficult to integrate them into educational and extension programs, due to their other roles and responsibilities. Women's active participation in fire management programs can be effective in protecting tropical forest resources from wildfires. The same can be said of the other members of the whole family unit. Adults, children, and elders must all be included in the solution.

Recommended Action 18

a. Include women as active participants in community based fire management activities; capitalizing on their knowledge and experience in the use of fire in agriculture, livestock production, and forest management.

b. Develop an effective fire education component, which is specifically directed towards women at the provincial and local levels. The transfer of fire management technologies, and the sharing of experiences may best be done through participatory programs and extension services in which women can play important roles.

7. LAND RESOURCES MANAGEMENT AND UTILIZATION

FOREST MANAGEMENT

Principle 19

Fire management is an integral part of sustainable forest management, which in turn should be based on appropriate land use planning, taking into account the views of all concerned parties.

Recommended Action 19

a. Integrate fire management considerations into forest management planning. For example, when making forest inventories, it is important to include information on the quantities of fuel, (dead tree, branches, litter), with a view to assessing the danger of fire.

b. Incorporate fire protection measures into forest concession contracts.

c. Include provisions for protection of the forest against fire when implementing silvicultural management practices.

Principle 20

Fire risk may be reduced by practicing increased forest diversity, particularly in plantations, in terms of species, age, and structure; as well as through preventative silvicultural techniques. Reducing fire occurrence lowers the forest's vulnerability to degradation from insects and disease.

Recommended Action 20

a. Consider the possibility of under-planting or intermixing the main canopy with suitable species of low flammability which are native to the area and already field tested.

b. Give priority to rehabilitation measures of fire damaged forests.

Principle 21

Savannas and grasslands are important tropical ecosystems, often interrelated with forest lands. Fire usually plays an important role in these ecosystems, and must be adequately managed in order to maintain the ecosystems and avoid damage to the nearby forests.

Recommended Action 21

a. Determine the appropriate fire regimes of the savannas and grasslands near forest areas, and develop fire management plans to address the requirements for sustaining those ecosystems.

b. Consider using prescribed fire and/or other techniques to prevent damage from free propagating wildfires in those ecosystems.

c. Instruct residents living within or near those ecosystems, which require periodic fire for their survival, on the proper use of fire, including adequate firing techniques.

FOREST UTILIZATION

Principle 22

Large forest areas are managed for timber production. Logging operations involve various activities including: the construction of infrastructure or facilities such as roads, camps, workshops, fuel storage, etc., the use of heavy equipment such as tractors, earth-moving equipment, skidders, trucks, vehicles, power saws, etc.. Workers have frequent access into forest areas, often throughout the year. These factors, combined with careless and poor equipment maintenance, or improper use, can increase fire risks.

Recommended Action 22

a. Logging operations and the use of all equipment and machinery must be strictly controlled, and clearly specified in concession agreements to reduce fire risks. Spark arresters should be used to prevent fires starting from chainsaws and other machinery. The handling, use and storage of gasoline must be strictly controlled with clear instructions; and placed under the responsibility of a designated person.

b. Concession holders, timber companies, and contractors should be encouraged to conduct special campaigns at regular intervals on fire hazards to promote greater consciousness and more responsible attitudes.

c. Specific guidelines must be developed for implementation during periods of extreme dry weather or high fire risk. Such measures may include total or partial restrictions on logging. It may be necessary to restrict access to forest areas to that required for logging operations in accordance with management plans and harvesting activities; including transport of logs to processing plants.

d. Concession agreements should specify the role and responsibility of the concession holder in cases of fire outbreaks, including participation in suppression action, and sharing the costs of rehabilitation of fire-damaged forests.

e. Concession holders, timber companies, and contractors should provide appropriate training for their employees, and develop operational procedures in fire prevention and suppression to promptly handle fire outbreaks during logging operations.

f. Concession agreements should require that concessionaires' crews and equipment be available for use in fire control activities.

Principle 23

Logging operations may result in accumulation of biomass, invasion by weed species, and desiccation of organic soil matter, all of which can increase fire risks. The careless use of fire during timber harvesting operations has resulted in large wildfires. These fires cause significant economic losses to governments who are often left with the responsibility for rehabilitating fire damaged forests.

Recommended Action 23

a. Plan logging operations to avoid creating large openings, which result in the drying of the forest floor, and invasion of fire prone pioneer species. Allow for techniques, (such as climber cutting), which minimize damage to surrounding trees.

b. Logging wastes should be minimized through a system of incentives and penalties that apply to concession holders and contractors. Where appropriate, encourage the use of logging residues by local communities, so long as this activity does not increase the risk of fire starts.

c. Laws, regulations, or codes of practice that apply to forest operators should be formulated and enforced; and if necessary, contractual arrangements modified to promote responsible fire protection by concession holders and contractors.

d. Penalties should be levied against concessionaires to recover losses of forest values and recoup costs for rehabilitation of fire damaged forests due to negligence.

OTHER FOREST USES

Principle 24

Communities living in and around forest areas have long-established traditions to hunt, to fish, and to collect food, medicinal plants, and other products from forest areas. Conversion of forests for other land uses, and population pressures, have increased the intensity of such uses by these communities, resulting in greater fire risks. Also, fire risks are greatly increased in forest areas through recreational and sporting activities.

Recommended Action 24

a. Concession holders, timber companies, and contractors should provide assistance to organize and provide support to local communities; encouraging their active participation in forest fire prevention programs.

b. Some forest based activities of local communities involve the use of fire. Such activities should be regulated through measures, which reduce the risk of wildfire starts from these activities.

c. Conflicts and misunderstanding between local communities and forest concession workers must be avoided through regular dialogues, and respect for local traditions and sensitivities. The welfare and well-being of local communities must always be considered by concession holders, timber companies, and contractors for any employment opportunities or facilities which become available.

d. Assist communities in their efforts to enhance respect for traditional values and customs, which have historically preserved natural resources.

e. During periods of extreme fire danger, access to forests for recreational pursuits should be strictly controlled. Camping should be restricted to certain sites where facilities such as stoves should be provided. Elsewhere, the use of fires for cooking should be prohibited.

f. Patrols should be undertaken in areas frequented by people to ensure compliance with rules and regulations in force. Such patrols should be more intensive during periods of high fire risks or during holiday seasons.

8. TRAINING AND PUBLIC EDUCATION

TRAINING AND EXTENSION PROGRAMS

Principle 25

Managers at various levels need to acquire and maintain knowledge of all aspects of forest fire management, as well as their responsibilities to maintain the health and sustainability of the forests. These managers include officials from forestry and other related ministries, as well as timber companies, contractors, and forest concession operators.

Recommended Action 25

a. Identify the information and training needs for relevant managers, and where necessary disseminate appropriate materials and conduct seminars, workshops, short courses, and field training sessions, dealing with the principles and application of forest fire management, including fire prevention and suppression.

Principle 26

People living near forests are often unaware that their activities may cause forest fires, and in some cases, can result in the destruction of forest ecosystems. Members of these communities, if motivated, properly trained and equipped, can be important sources of assistance in the prevention, control, and management of fires.

Recommended Action 26

a. Prepare and conduct courses for forest authority officers, concession holders, and contractor's staff for the "training of trainers" that can provide extension to local communities.

b. Identify and recruit suitable members of the community to be trained in fire prevention measures and in the use of techniques and equipment, (including traditional tools), to suppress and manage fires.

c. Prepare and conduct basic education programs, and provide extension materials for communities near the forest to increase their awareness on the importance of the forest environment and the role of fire.

d. When required, provide caches of basic fire suppression tools, under strict control of responsible individuals, to be used in emergencies by people identified and trained in "b" above.

Principle 27

Communities living near the forest have traditional values, which affect their attitude toward the forest as a living entity. Local people are influenced by community and spiritual leaders who are likely to be effective in extending information on fire protection.

Recommended Action 27

a. Seek the cooperation of the community and spiritual leaders in fire management programs.

Principle 28

Within their areas, the vigilance and influence of NGOs and women's groups can provide effective and prompt assistance in forest fire management programs.

Recommended Action 28

a. Develop and conduct courses as necessary for leaders of NGOs and women's groups on their roles in forest fire management programs, including the dissemination of information to the public on fire dangers to forest ecosystems; and the ways and means to reduce fire risks when enjoying the forest environment.

PUBLIC EDUCATION

Principle 29

Members of the public are affected by wildfires that result in the loss of wealth and livelihood and threaten forest ecosystems. Most people, including recreationalists, are unaware of the causes of fires, and their economic and ecological impacts.

The public's understanding of, and attitudes toward, the role and use of fire and forest management practices can best be improved through the education of children and youth.

Recommended Action 29

a. Establish or enhance cooperation between forest authorities and education departments to allow for the design of suitable curriculums, and the conduct of education programs for elementary and secondary schools on forest and fire management. Explore ways to include non-traditional allies in the education campaign against fire.

b. Use mass communication to provide information to the general public on the causes, impacts, and management of forest fires. The success of such public awareness campaigns will rely upon the selection of appropriate symbols and slogans, which help stimulate the general public to identify themselves with the message. Seek cooperation and involvement of religious organizations, civic groups, and NGOs in public awareness campaign.

c. Provide recreationalists with information (e.g. pamphlets, leaflets), on the benefits that fire steals from them, and on their responsibilities for the prevention of fires starting from campfires and other recreational pursuits.

d. Provide education on environmental issues, forest and natural resource management, and the impacts from wildfires at primary and secondary school levels.

Annex F

FAO/UNECE/ILO
Seminar on "Forest, Fire, and Global Change"
Shushenskoe (Russian Federation), 4-9 August 1996

The seminar on Forest, fire, and global change was held in Shushenskoe, at the invitation of the government of the Russian Federation from 4 to 9 August 1996, jointly organized with the UN-FAO/ECE/ILO Team of Specialists on Forest Fire. The following non-governmental organizations were represented: International Union of Forestry Research Organizations (IUFRO); the International Boreal Forest Research Association (IBFRA), Stand Replacement Working Group; and the International Global Atmospheric Chemistry (IGAC) Project, of the International Geosphere-Biosphere Programme (IGBP). The seminar addressed:

- Assessments on the extent of land areas affected by fire (forest and other land)
- Assessment of damages caused by wildfires
- Clarification of the role of forest fires in

    (a) land-use and land cover changes
    (b) ecosystems and in maintaining biodiversity
    (c) global carbon nutritient and water cycles
    (d) forests affected by industrial and radionuclide pollution
    (e) ecosystems affected by climate change

- Forest fire management, fire intelligence and equipment
- New spaceborne fire sensors

Based on these contributions the seminar formed working groups which prepared a general statement, conclusions, and recommendations which were adopted by the seminar participants (source: UNECE TIM/EFC/WP.1/SEM.44/2 dated 16 August 1996, also published in International Forest Fire News No.15, p. 40-47).

Conclusions and recommendations

1. General statement: The Role of Fire in the Global Environment

1.1 Both anthropogenic and natural fires are an important phenomenon in all vegetation zones of the globe. Their impacts, however, are not uniform. Fires may lead to the temporary damage of forest ecosystems, to long-term site degradation and to alteration of hydrological regimes which may have detrimental impacts on economies, human health and safety.

1.2 As a consequence of global population growth and land-use changes, the cumulative effects of anthropogenic disturbances, and the over-use of vegetation resources, many forest types, which over evolutionary time periods became adapted to fire, are now becoming more vulnerable to fire.

1.3 On the other hand, in many vegetation types, of the temperate, boreal and tropical ecosystems, fire plays a central role in maintaining the natural dynamics, biodiversity, carrying capacity and productivity of these ecosystems. In many parts of the world sustainable forestry and agricultural practices as well as pastoralism depend on the use of fire.

1.4 Vegetation fires produce gaseous and particle emissions that have significant impacts on the composition and functioning of the global atmosphere. These emissions interact with those from fossil fuel burning and other technological sources which are the major cause for anthropogenic climate forcing.

1.5 Global climate change is expected to affect fire regimes and lead to an increase of occurrence and destructiveness of wildfires, particularly in the boreal regions of continental North America and Eurasia.

1.6 Fire control has been the traditional fire policy in many parts of the world. An increasing number of countries have adopted fire management policies instead, in order to maintain the function of fire in removing the accumulation of fuel loads that would otherwise lead to damaging wildfires, and in order to arrest succession at stages that are more productive to humans than are forests and brushlands that would predominate in the absence of fire.

1.7 In many countries, however, inappropriate choices are made - often because the responsible authorities and managers are not provided adequately with basic fire information, training, technologies and infrastructures. Large-scale wildfire disasters which occurred in the past years, especially in the less developed countries, may have been less severe and extended if national fire management capabilities had been developed and assistance through the international community provided.

1.8 Although the global fire science community has made considerable progress to investigate global impacts of fire, using available and developing new technologies, no international mechanisms exist for systematically collecting, evaluating and sharing global fire information. There are also no established mechanisms at the international level to provide fire disaster management, support and relief.

1.9 Therefore the participants of the FAO/ECE/ILO Seminar on "Forest, Fire and Global Change" adopted the following conclusions and recommendations:

2. Conclusions

2.1 The economic and ecological impact of wildland fire at local to global levels has been demonstrated at this seminar. The possibility of major world disasters, such as the transfer of radioactive materials in wildland fire smoke, and the substantial loss of human life in recent fires, has been scientifically documented. The lack of, and need for, a global statistical fire database, by which the economic and ecological impact of fires could be spatially and temporally quantified, was identified. Such a reliable database is essential, under current global change conditions, to serve sustainable development and the urgent needs of fire management agencies, policy makers, international initiatives, and the global modelling community.

2.2 Similarities in wildfire problems throughout the world are evident, particularly increasing fire incidence and impact coupled with declining financial resources for fire management, underlying the urgent need to coordinate resources at the international/global level in order to deal effectively with impending major wildland fire disasters.

2.3 As climate change is a virtual reality, with predicted significant impacts at northern latitudes, seminar participants recognize that boreal and temperate zone fire activity will increase significantly in the future, with resulting impacts on biodiversity, forest age-class distribution, forest migration, sustainability, and the terrestrial carbon budget. It is essential that future fire regimes in these regions be accurately predicted, so informed fire management decisions can be made.

3. Recommendations

The seminar participants draw the attention of the Joint Committee to this serious situation and to expeditiously consider the following recommendations:

3.1 Quantifiable information on the spatial and temporal distribution of global vegetation fires is urgently needed relative to both global change and disaster management issues. Considering the recent various initiatives of the UN system in favour of global environmental protection and sustainable development, the ECE/FAO/ILO Seminar on Forest, Fire and Global Change strongly urges the formation of a dedicated United Nations unit specifically designed to use the most modern means available to develop a global fire inventory, producing a first-order product in the very near future, and subsequently improving this product over the next decade. This fire inventory data will provide the basic inputs into the development of a Global Vegetation Fire Information System.

The FAO should take the initiative and coordinate a forum with other UN and non-UN organizations working in this field, e.g. various scientific activities of the International Geosphere-Biosphere Programme (IGBP), to ensure the realization of this recommendation.

The information given in the Annexes I to III (Draft Proposals for the Development of a Standardized Fire Inventory System) to these recommendations describe the information requirements (classes of information, information use), the establishment of mechanisms to collect and distribute fire inventory data on a global scale.

3.2 The development of a satellite dedicated to quantifying the geographical extent and environmental impact of vegetation fires is strongly supported. Such an initiative is currently being evaluated by NASA, and this seminar strongly recommends that this and similar initiatives (e.g., NOMOS sensor on MIR space station) be encouraged and supported.

3.3 A timely process to gather and share information on ongoing wildfire situations across the globe is required. The creation of a WWW Home Page to handle this information flow is recommended. This could be coordinated with an ongoing G7 initiative, the Global Emergency Management Information Network Initiative (GEMINI), which includes a proposal to develop a Global Fire Information Network using the World Wide Web.

3.4 Mechanisms should be established that promote community self reliance for mitigating wildfire damages and would also permit rapid and effective resource-sharing between countries as wildfire disasters develop. Since the United Nations Disaster Relief Organization (UNDRO) is an organization recognized and established to coordinate and respond to emergency situations, including wildfires, it is recommended to entrust this organization, in collaboration with the United Nations Educational, Scientific and Cultural Organization (UNESCO), to prepare the necessary steps. The measures taken should follow the objectives and principles of the International Decade for Natural Disaster Reduction (IDNDR).[1]

3.5 The unprecedented threat of consequences of fires burning in radioactively contaminated vegetation and the lack of experience and technologies of radioactive fire management requires a special, internationally concerted research, prevention and control programme. Such programme should be implemented under the auspices of the FAO/ECE/ILO.

3.6 The Wildland Fire 97 International Conference in Canada should be used as a forum to further promote the recommendations of this seminar. This can be realized through co-sponsorship of this conference by the FAO, UNDRO, UNESCO, IDNDR and the ECE/FAO/ILO Team of Specialists on Forest Fire.

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[1] The participants of the Shushenkoe conference were not informed that UNDRO is not longer operational. At time of writing this report IDNDR is part of the UN Department of Humanitarian Affairs (DHA).

Appendix I: Draft Proposals for the Development of a Standardized Fire Inventory System

A Vegetation Fire Inventory System at both national and international levels serve a large number of practical needs:

1 Regional - national fire management
  a budget - resource requirements
  b daily to annual tracking of activity compared to normal
  c long-term trends
  d interagency - intergovernmental assistance
  e changes in long term trends

2 Regional - national non-fire
  a integrated assessments - monitoring of fire impacts on other resources
  b policies and regulations on
    i air quality
    ii global change
    iii biodiversity
    iv other

3 International use of fire inventory
  a updated forest inventory; availability of timber; fire integrated in resource availability salvage
  b market strategies
  c import- export policies - strategies
  d food and fibre availability rangelands
  e interagency - intergovernmental assistance agreements
  f national security
  g food and fibre assessment grass and fodder
    i
    ii water supply and quality
  h research
    i global change
    ii integrated assessments monitoring
  i international treaties agreements
    i UNCED
      - climate convention
      - biodiversity
    ii CSD, IPF
    iii Montreal protocol on ozone
    iv IDNDR, others

4 Economic data utility national, but not international compatibility of assumptions

Appendix II: Information Requirements

A. Classes of information

alpha type

- fire start and end dates
- fire location (lat, long; resolution?)
- fire size
- cause of fire

beta type
- fuels - biome classification
- fuel loading forest inventory, age class, size class

gamma type
- fire characterization (crown, surface, etc.)
- fuel consumption
- structural involvement (wildland urban interface)

delta type (current ECE/FAO)
- number of fires
- area burned (by forest type)
- cause of fires (number)

epsilon type
- gas and aerosol emission data

eta type
- total expenditure of fire programme
- total fire suppression costs
- total direct losses of merchantable timber, structural losses

B. Decision Space Table

Information use		Information type					Frequency
		alpha	beta	gamma	delta	eta	of info
Regional/National (fire)							
1	Budget resource requirements	x	x			x	A
2	Daily to annual fire activity	x	x	x		x	DWMA
3	Long term trends	x	x	x		x	A
4	Interagency agreements	x				x	DWMA
5	Resource allocation	x	x	x		x	DWM
Regional/National (non fire)							
6	Assessment monitoring	x	x				A
7	Air quality policy regulations	x	x		x		A
8	Global change policy regulations	x	x	x			A
9	Habitat change	x	x	x			A
International (fire)							
10	Intergovernmental assistance	x	x	x		x	DWMA
International (non-fire)							
11	Treaties and agreements	x	x	x	x		A
12	National security	x	x	x			DWM
13	Research		x	x	x	x	A
14	Market import/export forecasting	x	x		x	x	A

D = daily; W = weekly; M = monthly; A = annual

C. Parsimonious Fire Inventory

Intergovernmental assistance at bilateral or regional level does not require a global database. These agreements are regional and may differ in requirements from one region to another. If we exclude national security, we need only annual data for a global database. The gamma data type is assembled from the alpha data so there is no need to report this separately. The beta data on fuels can be obtained from other inventories, but must be standardized. The gamma data type will also require development of international standards before it can be considered. All vegetation fires must be included in this database.

Appendix III: Establishment of Mechanisms to Collect and Distribute Fire Inventory Data on a Global Scale

A. Current State of Fire Inventory

A Data consisting of individual fire reports are developed by many nations, but many regions of the world are not covered.
B Only ECE and EU nations have established mechanisms to share data.
C Current shared data consists of statistics aggregated from individual fire reports.
D Data from remote sensing is rapidly becoming available, but only for fires that can be defined by either heat signature or by fire scars on the landscape.

B. Issues

A A large number of uses of an international fire inventory have been identified in fire management, environmental policy and agreements, and in economic growth of nations.
B A parsimonious inventory has been identified which can be utilized by all nations (see statement on standardized fire inventory).
C There needs to be international agreement to provide fire inventory (similar to the FAO global forest inventory).

C. Implementation

A Fire inventory at the global scale should consist of individual fire data of date of fire start and end, location of fire, size of fire, and cause of fire. Fire location from individual fire reports normally report origin of fire. Remote sensed data are more likely to report centre of burned area. Should fire reports contain centre rather than origin, in addition to origin?
B Two additional forms of data will be needed in the future, biome classification and fire characterization. Standard for these additional information will need to be developed
C Rapid electronic communication is available for nearly all parts of the globe. Fire inventory data can be made available through World Wide Web. FAO is an appropriate centre to compile and distribute these data.
D Remote sensed data will need to be placed in the same format as individual fire reports and be made available on World Wide Web. Images can also be made available through WWW. Appropriate potential centres for compilation and distribution of these data are ISPRA (EU) or NASA's EOS-DIS.
F Those nations which cannot provide data in electronic format, should agree upon a hard copy format which can be scanned and readily placed in electronic format.

Annex G

WMO Workshop on Regional Transboundary Smoke and Haze in Southeast Asia, Singapore, 2-5 June 1998

Executive Summary

The World Meteorological Organization (WMO) organized a regional workshop on transboundary smoke and haze in Southeast Asia as part of its continuing response to forest fire episodes which caused widespread air pollution and environmental problems throughout the region. The Workshop was held in Singapore from 2 to 5 June, hosted by the Meteorological Service of Singapore and co-sponsored by the Asian Development Bank. Representatives from the National Meteorological and Hydrological Services (NMHSs), the ASEAN Specialized Meteorological Center (ASMC), Regional Specialized Meteorological Centers (RSMCs), and other agencies and organizations that are involved with fire-related activities, as well as invited experts, were in attendance.

The meeting focused on the 1997/98 smoke and haze episodes which interfered with civil aviation operations, maritime shipping, agricultural production, and the tourist industry. They also affected the health of populations in the region. The workshop was designed to foster regional and international cooperation through the review of what has been learned during the latest fire season, and to plan and coordinate implementation activities aimed at improving the NMHS's ability to manage transboundary smoke and haze episodes. This included discussions of regional plans such as the WMO Programme to Address ASEAN Regional Transboundary Smoke (PARTS) and the Regional Haze Action Plan (RHAP).

The workshop concentrated on operational aspects with emphasis on:

- The assessment of the current measurement systems and possible improvements to enhance regional capability in support of health and environmental assessments of smoke and haze effects;

- The regional capabilities to provide meteorological support during episodes of severe smoke, including the improvement of daily smoke trajectory and dispersion forecasts from the Atmospheric Transport Models (ATMs);

- The role of remote sensing in detecting and tracking fires, plumes, and aerosols and other emitted pollutants;

- Improvements in information exchange and coordination of activities among national authorities, NMHSs and international and regional agencies concerned with smoke and haze and other transboundary pollution events.

One major lesson learned from the Southeast Asian fire episodes is that smoke and haze do not recognize national boundaries. The fires last year were exacerbated by the El Niño related drought in the region which provided favourable conditions for large scale fires. It was also evident that the Meteorological Services played a critical role in the response to the smoke and haze problems. They contributed in valuable ways through:

(i) Daily meteorological monitoring and forecasting.
(ii) Specialized activities, that included hot spot identification using satellite imageries, haze trajectory modelling, compiling monthly and seasonal climate prediction information, and enhanced air quality monitoring activities.
(iii) The prompt dissemination of haze and smoke information to governmental agencies and the general public.

The fires of 1997/98 were looked at in comparison with earlier events. Records show that there have been at least nine widespread smoke and haze episodes in the region since the 1970s, occurring most frequently during El Niño periods. It is very likely that widespread smoke and haze episodes will occur again, especially as present plans call for continued large scale land conversion. Thus there is a pressing need for developing and implementing haze-related action plans.

The role of the Meteorological Services during the fire episodes is crucial. It is therefore important to strengthen their capacities for providing the timely warnings and forecasts needed to anticipate risks of future widespread smoke and haze episodes, and assist decision makers in managing these episodes. Towards this end, the following recommendations were developed at the Workshop.

RECOMMENDATIONS

The workshop formulated recommendations on modelling (A), remote sensing (B), measurements and monitoring (C) and information exchange (D).

A. Modelling

Enhance the regional capabilities to provide meteorological support in the form of improved predictions of ENSO/climate variability, daily smoke trajectories and dispersion forecasts by the use of Atmospheric Transport Models (ATMs), through:

(a-1). Improvement of regional climate prediction capabilities to interpret global forecasts.

(a-2). Development of flexible, situation-dependent programmes which allow for the provision of enhanced meteorological measurements (expanded frequency and spatial coverage) during periods of severe smoke and haze, and expanded use of satellite-derived meteorological products as input to models.

(a-3). Installation of trajectory/dispersion modelling capabilities at local meteorological services and utilization of local area modelling (LAM) capabilities in the region.

(a-4). Improvement of model performance through case studies and by conducting dry run exercises and possible tracer experiments.

B. Remote sensing

Improve the ability to characterize fire activity and track the movement of smoke and haze by strengthening present remote sensing capabilities by:

(b-1). Improvement of the operational aspects through provisions for back-up hot spot analysis capabilities, harmonization of fire counts by use of a single detection algorithm, through real time transmission of high resolution data on fires derived from satellites, and efforts to verify fire counts and burn-area information through ground-truthing activities.

(b-2). Expanded efforts to estimate aerosol and trace gas emissions from fires by combining fire counts with burn-area, along with a better characterization of sources in the diverse eco- and land-use systems.

(b-3). Promotion of the development of the next generation of satellites. This includes the need for a new NOAA channel-3 detector optimized for fire studies, dedicated fire satellites to monitor fires more precisely, and the use of space-borne radar for burned area and vegetation dryness assessment, and of lidar systems to measure the vertical distribution of trace gases and aerosols.

C. Measurements and monitoring

Strengthen regional monitoring efforts to assess the effects of smoke and haze on human health, to evaluate ecosystem impacts, to help validate atmospheric transport models, and characterize emission sources, by:

(c-1). Enhancement of existing monitoring networks to measure smoke and haze related quantities including aerosol mass ($PM_{2.5}$, PM_{10}), visibility, optical depth, and meteorological parameters. Two levels of observing stations are envisaged, a base level comprising fewer measurement parameters but with a high level of consistency across the network, and a second level with a more comprehensive measurement suite. At selected sites, targeted chemical quantities including aldehydes and other trace pollutants (CO, O_3, NO_x, VOCs, CO_2, SO_2), aerosol composition, and UV radiation are to be measured.

(c-2). Establishment of additional, including population-based, monitoring stations at areas not presently covered by existing networks (e.g., Kalimantan).

(c-3). Promotion of the scientific exchange of the validated measurement data, and the harmonization of the regional air pollution indices (API) used in regional smoke and haze alerts.

(c-4). Formulation of uniform protocols for sampling, including temporal resolution and reporting procedures. Expanding efforts directed at improvement of QA/QC, building upon the WMO Global Atmosphere Watch (GAW) programme components (WMO, GAW Report No. 113).

D. Information exchange

Improve the management of smoke and haze (and other transboundary) pollution events through efforts directed at enhanced information exchange and coordination, including:

(d-1). Enhancement of the current system for dissemination of data products and other relevant information, through the use of the GTS for meteorological data and gridded model outputs, and the Intranet and/or Internet systems for non-standard products.

(d-2). Increase the exchange of relevant information including meteorological data (especially rainfall), air quality data (including air pollution indices), and trajectory and plume forecasts. A critical element is the harmonization of data and output products to support effective real-time decision making.

(d-3). Coordination of emergency response responsibilities and activities between national Meteorological Services in the region, with the primary responsibility for the provision of information and forecasts to reside with the ASMC, but with the option of seeking further input from other RSMCs, and with provisions for bilateral arrangements.

(d-4). Improvements in existing mechanisms to regularly review the operational coordination between the NMHSs and activities related to the Regional Haze Action Plan, and to recommend changes and/or improvements to the plans.

(d-5). Development of linkages between the Meteorological Services and other national, regional and international organizations and scientific programmes with common interests, such as (IGBP/IGAC).

It was recognized that large-scale forest fires and the associated socio-economic and health-related problems occur frequently in other parts of the world as well, notably in South and Central America and Africa. It was recommended, therefore, that the deliberations of this workshop be reviewed by the organizations concerned in those regions. It was further strongly urged to organize as soon as possible an expert-level meeting to address the current situation in South and Central America.

The Workshop concluded with a plenary session which was joined by a delegation from the *Bi-regional Workshop on Health Impacts of Haze-Related Air Pollution*, organized by the WHO Regional Office for the Western Pacific, held in Kuala Lumpur, Malaysia, during 1-4 June 1998. The objectives of that meeting were to: Review haze-related air pollution problems and research findings; Identify further research needs to support haze-related decision-making; and Develop health protection measures/strategies. That workshop concluded that the haze episodes constituted a substantial health risk to the public as evidenced by the widespread exceedances of health-related air quality standards and guidelines for particulate matter (PM_{10} and $PM_{2.5}$), increased frequency of respiratory-related hospital visits in the most heavily impacted regions; increased frequency of attacks among asthmatic children; and reported persistent decreases in lung function among school children. The risk of long term health effects from these events is much more difficult to discern.

The representatives at the WMO Workshop recognized that the set of recommendations developed by the WHO and WMO workshops are complementary, and strongly encouraged closer cooperative activities between the meteorological and health related aspects of transboundary pollution.

Reference

WMO, GAW Report No. 131, WMO Workshop on Regional Transboundary Smoke and Haze in Southeast Asia (Singapore, 2-5 June 1998), World Meteorological Organization, Geneva.

Annex H

WHO BI-REGIONAL WORKSHOP ON HEALTH IMPACTS OF HAZE RELATED AIR POLLUTION

KUALA LUMPUR, MALAYSIA, JUNE 1-4, 1998

EXECUTIVE SUMMARY

Objectives of the workshop

The Bi-regional Workshop on Health Impacts of Haze-related Air Pollution was conducted in Kuala Lumpur, Malaysia from 1 to 4 June 1998 by the World Health Organization Regional Offices for South-East Asia and the Western Pacific.

The objectives of the workshop were:

(1) to review and summarize research findings and other relevant information concerning the impacts of haze-related air pollution on health;

(2) to identify needs for further technical information and research to support future haze-related decision-making; and

(3) to develop draft health impact reduction measures and strategies, addressing intercountry cooperation issues, for consideration by affected countries and external support agencies.

The workshop was attended by 17 participants and five observers from seven countries of South-East Asia and Papua New Guinea; four temporary advisers; ten representatives from seven international partner agencies; and four WHO staff serving as the workshop secretariat. The proceedings comprised presentations of country reports and haze-related health effects research activities by the participants; presentations of working papers by temporary advisers and representatives of international partner agencies; and plenary and group discussions on future research needs, health impact reduction measures, and inter-country cooperation.

The workshop deliberations produced conclusions in the following four major areas:

Conclusions in relation to haze-related air pollution problems and research findings:

(1) The haze episodes in South-East Asia in 1997 and early 1998 constituted a substantial health risk to the public.

(2) The main constituent of the haze that adversely affects health is particulate matter.

(3) From the existing body of knowledge that associates a range of adverse, non-cancer health impacts with urban particulate air pollution mixtures, there is no evidence that particles from different combustion sources have different impacts on health.

(4) The risk of long-term health effects due to a single air pollution episode is difficult to detect, but repeated exposures to haze episodes merit attention.

(5) To help ensure data comparability, it is desirable that consistent protocols be followed in relation to health effects monitoring, ambient air quality monitoring, and data analysis

(6) There are a number of valuable health-related research studies currently being carried out in the region.

Conclusions in relation to further research needs:

In addressing priority environmental health research needs, underlying emphasis always needs to be placed on research and public health monitoring capacity building. The priority needs identified in the region include:

(7) Research on new mitigation approaches:

- assessment the feasibility of different arrangements for "haze shelters"
- evaluation of the most effective approaches to management of a future haze emergency in terms of arranging transport to "haze shelters" for vulnerable groups, and other mitigation methods;
- evaluation of the effectiveness of remaining indoors; and
- evaluation of the effectiveness of early health care interventions, as well as public information and awareness efforts, in reducing health impacts.

(8) Research on the impacts of the 1997 haze, primarily using data that has been routinely collected:

- evaluation of short-term health impacts, including the identification of susceptible population groups;
- a regional study of short-term health impacts using standardized methodologies and routinely-collected data;
- assessment of any long-term effects in selected groups of exposed people in areas where comprehensive mortality and morbidity data are continuously maintained and
- identification of sources of particulate air pollution exposure, especially the relative contributions of biomass and motor vehicle-related urban air pollution mixture sources.

(9) Future research requiring the development of substantial new data:

- an assessment of the real effectiveness of the use of dust masks by the general population;
- an investigation of the availability of alternatives to masks which could be effective as personal protective equipment in mitigating health impacts;
- the delineation of the health impact mechanisms associated with biomass air

pollution; and
- an evaluation of the impact of specific pollutants on health (e.g., specific aspects of particulate composition, polycyclic aromatic hydrocarbons, and volatile organic compounds).

Conclusions in relation to health impact reduction measures/strategies:

Priority emphasis must be given to preventing and extinguishing fires.

(10) With regard to air quality monitoring and episode forecasting, from the health sector's perspective, information on the nature and extent of human exposure to environmental pollutants is essential to impact assessment.

(11) With regard to environmental control, for rural areas, individuals should reduce their level of physical activity and use masks when outdoors in the absence of other available measures. If possible, the infiltration of outdoor air should be reduced by closing windows, doors, etc.

(12) With regard to personal protection, properly sized and fitted respirators can provide protection for essential workers who must remain outdoors for extended periods of time during haze episodes. However, the use of masks for the general population should be the lowest priority in terms of health mitigation measures.

(13) Public health monitoring needs to be considered as a routine component of health sector operations during and after haze episodes.

Conclusions in relation to intercountry and inter-organizational cooperation and coordination:

(14) Inter-country cooperation needs to be implemented through existing regional coordination mechanisms.

(15) Areas in which regional cooperation is suggested include the following:

- the development of air pollution epidemiology guidelines to harmonize research methodologies and data collection and analysis;
- the implementation of joint studies on the health impacts of the 1997 haze, including the assessment of needs for air quality monitoring data from a public health point of view;
- the strengthening of human resources and national capacity in air pollution epidemiology and air pollution and public health monitoring;
- the establishment of a regional information clearing house on haze-related health impact research; and
- the organization of regional forums and participation in international meetings.

(16) Proposals for specific projects in the above areas of cooperation will be prepared by participants from countries with interest and expertise.

(17) International and bi-lateral partner agencies are encouraged to take up and support, in a coordinated fashion, the issues reflected in the deliberations of this meeting and summarized in these conclusions.

WHO BI-REGIONAL WORKSHOP ON HEALTH IMPACTS OF HAZE-RELATED AIR POLLUTION

Kuala Lumpur, Malaysia. June 1-4, 1998

SUMMARY OF COUNTRY REPORTS

Brunei Darussalam

Since 1982, several episodes of haze have occurred in the country. The haze episode of 22-30 September 1997, although air pollution levels were not recorded, was clearly worse than the previous episodes. From February to April 1998, during which the dry weather prevailed, the Pollution Standard Index (PSI) readings exceeded 100 and climbed as high as 250, causing the disruption of daily activities, closure of schools and changes in government working hours. Morbidity surveillance by the Ministry of Health indicated increases in hospital visits during the peak haze months.

The government action taken to respond to the haze includes:

- the establishment of a National Committee on Haze in September 1997
- the development of a National Action Plan with health guidelines.
- the fighting of local fires; distribution of respiratory masks for school children
- the installation of one fully equipped air monitoring station and eight PM_{10} monitoring stations
- the promulgation of more stringent law on open burning
- the provision of public information and education through Haze Information Center and pamphlets,
- a stock of emergency supplies; and
- cooperation with other neighboring countries through regional coordinating mechanisms.

Indonesia

The 1997 forest fires covered 12 provinces of Indonesia in the islands of Sumatra, Kalimantan, Maluku and Irian Jaya, burning an estimated 165,000 hectares. During the peak haze period of September and October 1997, significant increases in asthma, bronchitis and ARI were observed in 8 provinces. About l, 800,000 cases of these diseases were reported among the estimated l2,360,000 persons affected by the haze. Under the coordinating Minister of Social Welfare measures were undertaken to reduce and mitigate the impact of the fires with the cooperation of neighboring and other countries which provided technical and material support in fire fighting, air quality monitoring and personal protection measures. During the peak period of air pollution in the first week of October, total suspended particulate (TSP) levels exceeded the national standard by 3-15 times. In Jambi, North Sumatra and Central and South Kalimantan, the TSP values were 15 times the national standard during the second week of October 1997. No active PM 10 monitoring was available during the haze period.

In order to increase the awareness of the community and minimize the health impact of the haze, provincial health offices were instructed to monitor air quality, strengthen the surveillance of haze-related diseases, distributed masks to high risk group and alerted private and government health services to provide 24-hour service. In addition, guidelines were developed for health personnel to respond to haze related emergencies and a study on the long-term health effects initiated, and an information and early warning system set up for future haze disasters. In February l998 a joint Ministry of Health-WHO training programme on PM_{10} air quality monitoring was conducted for provincial health personnel as part of the process of establishing a PM_{10} monitoring system for early warning and disaster preparedness in event of another haze episode.

Malaysia

The 1997 haze occurred between August and October with the highest Air Pollution Index (API) of 850 observed in Kuching, Sarawak. Health Surveillance data collected in Klang Valley showed increases in cases of upper respiratory tract illness, asthma and conjunctivitis in association with API values. A haze struck Miri, Sarawak in February and March 1998 with the highest recorded API reading of 649 on 30 March. There was a definite increase in the cases of upper respiratory tract illness associated with increased API values.

The activities carried out to respond to the haze episodes include

- the setting up of the Ministry of Health operations room in September 1997;
- the implementation of health surveillance;
- the provision of health guidelines;
- the provision of public information through media;
- participation in interagency collaboration through the National Haze Committee; and
- the preparation and implementation of the Standard Operating Procedure for response to haze.

Papua New Guinea

During the later part of 1997, the haze problem affected some parts of Papua New Guinea. Because of he prevailing wind conditions at that time, it is believed that much of the pollution contributing to this problem came from forest fires in Indonesia and bush fires in Australia. In addition, the problem was made worse by some bush fires in Papua New Guinea itself. The fires in Papua New Guinea were more troublesome than would normally be expected because of the significant drought conditions that existed in the country. During the month of September, the severity of the haze problem was reflected in the cancellation of about 50 percent of the commercial airline flights.

Although no ambient air quality measurements were available, during the peak haze period visibility in the city of Port Moresby (which was considered the worst area) was about 1 kilometer. Also, although no special health impact surveillance effort was undertaken, anecdotal evidence suggests that there was an increase in the incidence of respiratory-related disease problems. Analysis of routinely collected health data, however, did not indicate a statistically significant increase in the level of these diseases.

Because of the relatively minor impact of the haze problem in Papua New Guinea, mitigation measures undertaken by the Government focused on education and information dissemination activities to minimize the traditional slash and burn practices among subsistence farmers. Overall, the concerns for the future relate more to the adverse impacts of the El Nino

Phenomenon (e.g. the severe drought conditions and associated shortages of food and safe drinking water) than to a repetition of the haze problem

Philippines

The long dry period caused by the El Nino phenomenon affecting the Asian region, particularly during the months of August and September 1997 aggravated forest fire problems in Indonesia and raised concern in the Philippines about the possibility of the significant transboundary movement of the associated air pollution. The Philippines joined other ASEAN countries in monitoring haze and related air pollution. In September, the Department of Environment and Natural Resources (DENR) created the Haze task Force, composed of representatives from various government agencies. The agencies involved are the DENR, Environmental Management Bureau, the Department of Health, the Department of Science and Technology – PAGASA, the Metropolitan Manila Development Authority, the Department of Interior and Local Government and the Department of Trade and Industry. The responsibilities of the task forces were/are:

- to monitor the movement of haze caused by forest fires in Indonesia and will serve as the official source of information on haze-related issues
- to determine the health hazards accompanying such degree of haze density and accordingly take care of announcing the same to the public, including mitigation measures through bulletins and the print media; and
- to coordinate with other government agencies as may be required

The impacts of the haze from forest fires in Indonesia were noted primarily on the southern islands of Palawan and Mindanao. While no specific ambient air quality measurements of fine particulate matter were available, the visibility in these areas was reduced to about 4-5 kilometers for several days. No particular health directly related to the haze problem was noted.

In January 1998, the Haze task Force formulated the national Haze Action Plan in accordance with the request of the Regional Haze Task Force for ASEAN. The Philippines has participated in the series of ministerial and Regional Task Force meetings on the haze problem in Singapore, Malaysia and Brunei. In addition, a comprehensive information campaign on haze and related air pollution, emphasizing prevention, control and protection measures, is planned.

Singapore

There are 15 air quality monitoring stations throughout the country. Of these 12 are ambient stations and three roadside stations. During the 1997 haze period, the Pollutant Standard Index (PSI) was over 100 for 12 days with the highest reading of 138. About 94 per cent of haze particles were found to be less than 2.5 μm in diameter. Health surveillance showed a 30 per cent increase in hospital attendance for haze-related illnesses. An increase in PM_{10} levels form 50 μg/m3 to 150 μg/m3 was significantly associated with a 2 per cent increase in cases of upper respiratory tract illness, 19 per cent increase in cases of asthma and 26 per cent increase in cases of rhinitis. No significant increases in hospital admissions or mortality were observed.

Health advisories were given to the public and National Haze Task Force was established. A national Haze Action Plan was prepared, which would be activated when the 24-hour PSI level exceeds 50. The action will be stepped up when the PSI level reaches 200.

Thailand

The haze from the Indonesian forest fires were observed in the Southern provinces of Thailand on 22 September 1997 with a sudden increase in daily PM_{10} concentration of 20 µg/m3 in the city of Hatyai. The first peak haze episode lasted from 22 to 29 September with a Maximum peak of 211 µg/m3 followed by a second haze peak episode during 6-8 October. Although forest fires continued in Indonesia there was no significant transboundary haze episode after these two periods.

Because of the abrupt nature of the haze and lack of experience by the authorities, the response to the haze episode occurred relatively late. In response to public demand for local air quality data, the initial emphasis of the response was on monitoring air quality rather than on prevention and mitigation measures. Ordered by the Cabinet, the Ministry of Heath set up a coordinating centre for public support and appointed its committee 3 October 1997. A total of 140,000 masks were distributed in all southern provinces in early 1997. The committee appointed a subcommittee on public information and risk communication as well as to advise on protection measures. A set of guidelines for public support during haze was produced covering such aspects as air quality monitoring, health risk communication and public advice on protection measures as well as the roles of different agencies in public support. Advice on protection measures covered suggestions for susceptible population groups and the general population. Guidelines were produced for assessing public health impacts in province.

Subsequent post-haze activities included the generation of air quality monitoring and meteorology data for haze early warning system. A multidisciplinary retrospective study to evaluate changes in meteorological conditions, air quality and health effects, and a study on the records of outpatient visits and inpatient admissions in Hatyai indicated increases in respiratory illnesses related to the haze.

Annex I

United Nations International Decade for Natural Disaster Reduction (IDNDR) Early Warning Programme

Extract from the Report on

Early Warning for Fire and Other Environmental Hazards

Convener of International Working Group, and first Author:

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IDNDR Secretariat, Geneva October 1997

FOREWORD

In 1989, the member states of the United Nations declared the period from 1990 to the year 2000 to be the International Decade for Natural Disaster Reduction (IDNDR). Its objective is to "reduce the loss of life, property damage, and social and economic disruption caused by natural disasters, through concerted international action, especially in developing countries".

The fundamental importance of early-warning for realizing this objective of disaster reduction was recognized in 1991. The IDNDR's International Scientific and Technical Committee declared the subject a programme target, by which the success of the Decade would be judged by the year 2000. By drawing on global scientific knowledge and practical experience, the IDNDR advisory committee encouraged all countries to ensure the ready access to global, regional, national and local warning systems as part of their national development plans. The IDNDR Secretariat has since coordinated an international multi-disciplinary framework to promote this issue. In doing so, it has been able to draw on the comprehensive views and abilities of the United Nations system, needs and concerns of individual countries, and related global expert knowledge.

The critical nature of early-warning for the protection of vital resources and for addressing national development objectives was highlighted by a technical committee session devoted to the subject at the United Nations' World Conference on Natural Disaster Reduction held in Yokohama, Japan in May 1994. Several of the expert presentations cited the importance of public policy commitment for successful early warning. The primary outcome of the Conference, ***The Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation*** further emphasized the importance of applied scientific knowledge and the public's awareness of hazard risks as essential components for more effective early warning practices.

The IDNDR Secretariat was requested by the United Nations General Assembly in 1995 to coordinate a programme to review the existing early warning programmes within the United Nations system and to suggest means by which global practices could become better coordinated and made more effective. Initial information was conveyed by the ***Secretary General's Report on Early Warning to the Fiftieth Session of the United Nations General Assembly*** in October 1995. At that time, a further examination of new scientific and experimental concepts for accurate and timely short-term forecasting was requested of the IDNDR for the purpose of making recommendations on the applicability and development of more effective early warning in the context of international cooperation

For the current work, six international expert working groups were convened to study different dimensions of the early warning process. Individual groups reviewed aspects of early warning as they related to geological hazards, hydrometeorological hazards including drought, fire and other environmental hazards and technological hazards. Other groups concentrated on the use and transfer of related modern technologies, and national and local capabilities pertinent to the effective use of early warning.

The following titles compose the series of information reports of the IDNDR Early Warning Programme:

Early Warning Capabilities for Geological Hazards
Early Warning for Hydrometeorological Hazards, Including Drought
Early Warning for Fire and Other Environmental Hazards
Early Warning for Technological Hazards
Earth Observation, Hazard Analysis and Communications Tech. for Early Warning
National and Local Capabilities for Early Warning
Guiding Principles for Effective Early Warning

The Secretary General's Report on Early-warning Capacities of the United Nations System with Regard to Natural Disasters presented to the Fiftieth Session of the United Nations General Assembly, October 1995. (UN doc. A/50/526).

The Secretary General's Report on Improved Effectiveness of Early-warning Systems With Regard to Natural and Similar Disasters presented to the Fifty-second Session of the United Nations General Assembly , October 1997. (UN doc.A/52/561).

These reports may be accessed on the IDNDR Website at www.idndr.org. They also may be obtained from the IDNDR Secretariat, Palais des Nations, CH-1211 Geneva 10 Switzerland. or by Fax: 0041-22-733-8695, or E-mail: idndr@dha.unicc.org

This present report of the expert group on Early Warning for Fire and Other Environmental Hazards represents global experience and reviews the current state of knowledge and practice on the subject. Recommendations are also made for improvements and areas that require additional international attention. The consensus views include major contributions from scientific and technical experts of different professional disciplines as well as the participation of United Nations departments and agencies concerned. An effort was made to ensure that views of government authorities, non-governmental organizations and other elements of civil society were also represented, particularly as they relate to factors which determine the efficacy of early warnings.

This report is one of a series issued by the IDNDR Secretariat in October 1997 to trace efforts in reviewing the current global state of early warning systems. By the end of the Decade, these views will contribute to final recommendations for improved, and better coordinated, practices in fulfilment of the initial IDNDR programme target for the subject. They will first be considered by an International Conference on early warning systems for the reduction of natural disasters to be held in Potsdam, Germany in September, 1998. This technical and scientific conference focussing on the application of successful warning practices will be sponsored by the Government of Germany with the collaboration of United Nations agencies and international scientific organisations. As a major topical event of the IDNDR closing process and the consolidation of global views, it will work to identify those accomplishments and local experiences which can best inform improved organizational relationships and practical effectiveness for early warning into the 21st century.

Recommendations by the IDNDR Early Warning Working Group on Fire and Other Environmental Hazards

In accordance with the conclusions and recommendations given by the various international initiatives, the IDNDR Early Warning Working Group on Fire and other Environmental Hazards comes to the following recommendations for priority activities:

i) **A global fire inventory must be designed and implemented, producing a first-class product in the very near future, in order to provide a basis for early warning systems. Subsequently, this product then must be improved for standardized application over the next decade.**

   Fire inventory data is necessary to provide the basic inputs into the development of a future relational (geo-referenced) global fire database within the proposed Global Vegetation Fire Information System (GVFIS). FAO should take the initiative and coordinate a forum with other UN and non-UN organizations working in this field, including various scientific activities of the International Geosphere-Biosphere Programme (IGBP) and the mechanisms of the Intergovernmental Panel on Climate Change (IPCC, 1997).

ii) **A timely process to gather and share real-time information about ongoing wildfire situations on a global basis is required.**

   This follows a proposal to create the World Fire Web in which a network of centres with facilities to receive and process fire observation data from satellites will be connected via the World Wide Web (WWW). Through the World Fire Web scientists, managers, and policy makers can have instant access to local, regional and world data so that they can can exchange experiences, methods and trouble-shoot with each other. The World Fire Web, in conjunction with the space borne evaluation of vegetation dryness, fire-weather forecasts and the possibility of forecasting fire danger and fire behaviour may provide a powerful early warning and disaster preparedness and management tool at national, regional and global scales. The information network should include the resource status by continuously monitoring the disposition of suppression resources. This includes the location and status of individual resources as well as potential availability for inter-agency and international mobilization.

iii) **Technology transfer and information exchange on early warning and fire management decision support systems must be provided through international collaborative agreements or technical assistance programmes.**

Such programmes must support countries in fire-prone regions of the tropics and subtropics where advanced fire management systems are not yet fully available.

iv) **The development of space borne sensor technologies devoted to the specific tasks of recognizing wildfire disaster precursors, fire activities, and the impacts of fire (ecological, atmospheric, chemical) must receive high priority.**

v) **Additional fire research is needed in those locations where existing early warning systems cannot be applied due to the particular relationships between vegetation, local/regional weather and prevailing socio-economic or cultural conditions which contribute to wildfires and their secondary damages, such as atmospheric pollution.**

South East Asia is one of the less explored regions in which fire research must receive adequate attention as proposed by the ASEAN Transboundary Haze Pollution initiative as well as by the IGBP global-change oriented science programmes. These include the South East Asian Fire Experiment (SEAFIRE) and the SARCS Integrated IGBP/IHDP/WCRP Study on Land-use Change in Southeast Asia.

vi) **Policies and agreements on environmental protection at international levels should ensure that in the implementation of Agenda 21 for forests, due attention is given to forests fires in relation to arrangements that may be developed to harmonize and promote international efforts to protect the world's forests.**

vi) **The suggestion of ITTO to establish a UN-sponsored facility for global fire research and management is endorsed to facilitate the development of the proposed Global Vegetation Fire Information System**.

This is considered essential in order to provide support on request to any nation in early warning, prevention, management and mitigation of wildfire disasters.

Annex J

The Global Fire Monitoring Center (GFMC)

Data Archiving and Information Distribution: Location and Access to the Global Fire Monitoring Center

1. Rationale

In many vegetation types of the globe the application of fire in agriculture and pastoralism and the occurrence of natural wildfires (natural fire regimes) are established (beneficial) elements in traditional land-use systems, in natural ecosystem processes and in biogeochemical cycles.

Excessive application of fire due to rapid demographic and land-use changes, however, lead to destruction of productivity, carrying capacity, biodiversity and vegetation cover. Climate variability such as periodic extreme droughts caused by the ENSO phenomenon add to the severity of fire impacts. Projected demographic and climate change scenarios suggest that this situation will become more critical during the next decades.

The state of fire science (fundamental fire research, fire ecology) in most vegetation types, and the results of biogeochemical and atmospheric sciences research of the last decade provides sufficient knowledge for supporting decision making at fire policy and management levels.

It is observed, however, that in many countries the expertise is either not known or is not readily accessible and available for developing adequate measures in fire policies and management. The fire and smoke episode of 1997-98 in South East Asia was a good example that existing fire information systems or fire management expertise was utilised to a limited extent only. These circumstances led to confusion at national and international decision-making levels. Several national and international projects were delayed or missed the targets.

This can be explained by the lack of a regional South East Asian or - considering global fire problems - a global fire information system.

Consequently, an information and monitoring system is needed which national and international agencies involved in land-use planning, disaster management or in other fire-related tasks can utilise for planning and decision making.

2. The Global Fire Monitoring Centre

The Global Fire Monitoring Centre (GFMC) has been established in June 1998 in accordance with

- The objectives of the UN International Decade of Natural Disaster Reduction (IDNDR)

- The recommendations of the ITTO Guidelines on Fire Management in Tropical Forests, and

- The recommendations of various scientific and policy conferences in the field of fire, e.g. the FAO/ECE/ILO Conference "Forest, Fire and Global Change" (Russia 1996)

For its first phase the GMFC is sponsored by the government of Germany, Ministry of Foreign Affairs, as a German contribution to the IDNDR. The fire documentation, information and monitoring system is accessible through the Internet:

<http://www.uni-freiburg.de/fireglobe>.

The GFMC is established at the Fire Ecology and Biomass Burning Research Group of the Max Planck Institute of Chemistry, Germany. Since the begin of the 1990s the Max Planck Institute has been responsible to design, co-ordinate, organise and partially implement several international fire research campaigns under the umbrella of the International Geosphere-Biosphere Programme (IGBP). The institute is chairing the scientific steering committee of the fire science component within the IGBP (the Biomass Burning Experiment [BIBEX]) and hosts the BIBEX Secretariat, located at the GFMC.

Since the early 1990s the Fire Ecology Research Group in addition has taken the lead in the UN system through its role as co-ordinating unit of the UN-FAO/ECE/ILO Team of Specialists on Forest Fire. The UN team serves the UN agencies and all other national and international partners in providing information and links in the field of global fire. Since 1988 the UN Team is publishing the UN International Forest Fire News (IFFN) which is distributed to nearly 1000 agencies, institutes, libraries and individuals world-wide. Starting in 1998 the IFFN is globally accessible via the GFMC Internet website.

Furthermore, the Fire Ecology Research Group is convenor of the IDNDR Early Warning Programme Working Group "Fire and Related Environmental Hazards".

3. Design of the GFMC

Following the principles which were developed for a scientific Global Vegetation Fire Information System in the early 1990s, the Global Fire Monitoring Centre will document archived and provide real-time or near-real time information related to fire. This will include the interlinking with other national, regional and international information systems.

In the case of the successful creation of a Global Disaster Information Network (GDIN) or similar initiatives the GFMC may contribute to the fire component within such global information systems. Contacts at the working level are established with GDIN which is a initiative by the U.S. government.

4. Co-Sponsors of the GFMC

The GFMC is co-sponsored by several international and national organizations.

4.1 Confirmed Co-Sponsors

UN-ECE Trade Division: The UN FAO/ECE/ILO Team of Specialists on Forest Fire, an activity of the UN-ECE Trade Division, Timber Section (Geneva), is the main co-sponsor at the UN level. The leader of the team is identical with the head of the GFMC. The UN-ECE fire team produces the IFFN which provides the core of archived fire documentation.

International Decade of Natural Disaster Reduction (IDNDR): The UN decade has already agreed to be co-sponsor and put its logo on the homepage of the GFMC. The GFMC directly contributes to the overall IDNDR objectives, particularly within the frame of the IDNDR Early Warning Programme.

World Conservation Union (IUCN): The IUCN has joined the GFMC as a co-sponsor in 1999. IUCN and GFMC jointly address global fire in cooperative projects with the World Wide Fund for Nature (WWF) and the Global Environment Facility (GEF) (in preparation in 1999).

The International Union of Forestry Research Organizations (IUFRO): Through the IUFRO Forest Fire Research Group S8.05

The International Boreal Forest Research Association (IBFRA): Through the Fire Working Group

The International Geosphere-Biosphere Programme (IGBP): Through the International Global Atmospheric Chemistry IGAC) Project, the Biomass Burning Experiment (BIBEX)

The U.S. Bureau of Land Management (BLM): As financial sponsor of the UN-FAO/ECE International Forest Fire News

Regional programmes: Two regional programmes are already linked to the GFMC.

- The ASEAN Regional Technical Assistance "Strengthening ASEAN's Capacity to Prevent and Mitigate Transboundary Atmospheric Pollution Resulting from Forest Fires" (financed by ADB) closely co-operated with the GFMC. The ASEAN Fire/Haze Information System is connected to the GFMC website.

- As a consequence of the First Baltic Conference on Forest Fires it was agreed to establish a Baltic Focus activity in which all countries bordering the Baltic Basin will collaborate. The Baltic Focus activity is identical with a regional activity of the UN-ECE fire team. The Baltic Focus aims to contribute to the BALTIC 21 Agenda.

4.2 Proposed Co-sponsors

The International Tropical Timber Organization (ITTO): The ITTO has taken the lead to develop globally recommended fire management guidelines (ITTO Guidelines on Fire Management in Tropical Forests). The Fire Ecology Research Group which hosts the GFMC has supported the development of the guidelines, including a follow-up at national level (Indonesia).

FAO: The FAO has been approached in the frame of the consultation on Public Policies Affecting Forest Fires (Rome, 28-30 October 1998). The GFMC is envisaging to commonly develop a Global Vegetation Fire Inventory (GVFI) to be conducted under the auspices of the FAO, initially in the frame of the Global Forest Resources Assessment 2000. The GFMC and the UN-ECE Fire Team have already proposed an outline of a global fire inventory/statistics system. In 1999 the FAO has entrusted the GFMC to prepare the Update of the FAO Wildland Fire Management Terminology (FAO, 1986).

WHO: The GFMC has contributed to the development of the WHO Health Guidelines on Vegetation Fire Events.

WMO: The GFMC assisted the WMO to prepare a strategic regional SE Asian Transboundary Haze Pollution action plan. Future similar activities of the WMO will be important links for the success of the GFMC and vice-versa. At present the WMO is being approached formally.

UNEP: The UN Fire Team has offered to assist UNEP in their task to co-ordinate the UN response to fires in Indonesia. First letters have been exchanged between the GFMC and UNEP Executive Director.

The World Bank: The newly established Disaster Management Facility has been contacted and first informal talks on possible collaboration through trust fund financing have been held.

The European Commission: Request in preparation to support the GFMC by providing the continuously updated EU fire database.

Annex K

WHO Expert Task Force

on the

HEALTH GUIDELINES FOR FOREST FIRES EVENTS

WHO-UNEP-WMO Guidelines Workshop
6 – 9 October 1998, LIMA – PERU

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Annex L

International Programmes

The Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization

Within the United Nations system the World Meteorological Organization has a continuing responsibility for providing authoritative scientific information and advice on the state and behaviour of the earth's atmosphere and climate using a number of its operational observation networks, one of which is GAW. The GAW system is designed to co-ordinate two related atmospheric chemistry environmental problems: 1) To understand the relationship between changing atmospheric composition and changes of global and regional climate 2) To describe the regional and long-range atmospheric transport and deposition of natural and man-made substances. The goal of GAW is to ensure long-term measurements and related assessments.

The GAW consists of a Global network of currently 22 stations in pristine areas, which measure key variables and serve as standards for other stations in their region. In addition, a Regional network of about 300 stations making atmospheric chemistry measurements are located closer to the source areas. The national meteorological and hydrological services (NMHSs) and other national institutes are responsible for the sampling in the GAW programme. In substantial efforts to broaden the GAW network coverage, six new Global stations have been recently established in collaboration with the United Nations Development Programme (UNDP) and supported through the Global Environment Facility (GEF). One of these stations, Bukit Koto Tabang, Indonesia, provided valuable information during the 1997 smoke and haze episode.

Greenhouse gases (CO_2, CFCs, CH_4, N_2O, tropospheric O_3), ozone (surface, total column, vertical profile), reactive gas species (SO_2, NO_x, CO, VOCs), chemical composition of precipitation, chemical and physical properties of atmospheric particles (including aerosol optical depth), solar radiation including ultraviolet UV, radionuclides and meteorological parameters comprise the complete measurement programme of GAW Global stations. To ensure the required quality of data a number of measurement guidelines have been introduced by WMO.

WMO has established six World Data Centres to collect, process, analyse and distribute data obtained from the GAW stations: ozone and UV radiation (Canada), surface ozone (Norway), greenhouse and other trace gases (Japan), precipitation chemistry (USA), solar radiation (Russia) and aerosols (EU, Italy). The GAW data are available directly from the Centres upon request from all organizations, scientific institutions and individual scientists.

Scientific Advisory Groups (SAG) have been formed to give scientific guidance for the different components of GAW to complete the range of specifications and tools for observation and management, including quality assurance. The activities of the SAG on UV Radiation, SAG on Ozone and the Aerosol SAG are most closely tied in with the smoke and haze episodes. As is also mentioned in these health guidelines, according to present knowledge the most hazardous emissions from fires on human health are aerosols. The WMO Aerosol SAG has identified stations that have the potential to monitor biomass burning.

Many of the WMO Members need to develop skills and expertise required to manage their environment and natural resources in a sustainable manner. To assist, the GAW has introduced education and training activities, which are centered around atmospheric chemistry. Participating with WMO are a number of non-governmental, international research, multinational and governmental organizations. The transfer of expert knowledge and technology, a vital aspect of GAW, is accomplished through academic capacity building for developing countries especially by encouraging twinning or long-term partnership. Training is also accomplished through workshops and special tutorial events.

All of the above GAW activities are directly relevant to monitoring the chemical emissions from smoke and haze episodes. The Atmospheric Research and Environment Programme (AREP) department of WMO has played a very active role in the fires issue in Southeast Asia. An overview of national and regional capabilities to detect, monitor and track smoke and haze, and modelling and satellite capabilities was obtained during the visit in 1996 of Dr. Bolhofer and Prof. Carmichael. This resulted in the Program to Address ASEAN Regional Transboundary Smoke (PARTS) proposal. During the 1997 fires episode, there was an expert visit from the Secretariat to the region.

As a result of the above activities and requests from the WMO Members in the region the "WMO Workshop on Regional Transboundary Smoke and Haze in South-East Asia" was arranged in Singapore in June 1998. The report has been distributed; copies are available upon request from the Secretariat. The role of WMO will be to assist in enhancing the regional capabilities to provide meteorological support in the form of improved predictions of ENSO/climate variability, daily smoke trajectories and dispersion forecasts by the use of Atmospheric Transport Models (ATMs) and in improving the ability to characterize fire activity and track the movement of smoke and haze by remote sensing capabilities. The WMO will also provide assistance in strengthening regional monitoring efforts and to improve the management of smoke and haze (and other transboundary) pollution events through efforts directed at enhanced information exchange and coordination. The recommendations from the WMO workshop can be found in Annex G.

For many of WMO Member countries, a major environmental problem is urban/regional air quality. This is particularly true in developing countries where there has been an explosive growth of urban pollution that, in addition to the direct impact on the local environment, affects the surrounding regions. It is clear that urban activities, when taken collectively, have a profound impact on the environment at all scales, including global. It is also in urban/regional areas, where people have suffered from the transport of smoke and haze on various scales.

Recognizing that WMO has a critical role to play in the study and management of urban environments, the Thirteenth World Meteorological Congress (May 1999) concurred withactiontaken by the Executive Council and the Commission for Atmospheric Sciences to establish an urban environment meteorological research programme. This will be accomplished through GAW. Actionwill be initiated to increase coordination and focus on present activities as well as toward selected new endeavours.

The GAW Urban Research Meteorology and Environment (GURME) project will be built upon a two pronged strategy. One prong would be focused on providing *assistance* to NMHSs in developing countries in enhancing their capabilities to deal with urban meteorological and environmental issues. The second prong would be directed towards the *coordination* of urban meteorological and environmental initiatives and efforts to better define the relationships and linkages between urban environments and sustainable development, and between local, regional and global environmental problems. GURME will cooperate with other WMO Programmes as well as UN Agencies (e.g., WHO and UNEP), international programmes and institutions with urban interests.

GURME will be centred on the traditional activities related to meteorological monitoring, forecasting, and modelling (both meteorological and chemical) and their application to air quality problems. These activities will be facilitated by enhancing the capabilities of NMHSs to handle the meteorological and air quality aspects of urban pollution, both in research and operational modes.

The Healthy Cities Air Management Information System AMIS of the World Health Organization

The Air Management Information System (AMIS) is a programme developed by WHO under the umbrella of the Healthy Cities Programme. AMIS has the objective to transfer information on air quality management (air quality management instruments used in cities, indoor and ambient air pollutant concentrations, noise levels, health effects, control actions, air quality standards, emission standards, emission inventories, dispersion modelling tools) between countries and cities. In this context AMIS acts as a global air quality information exchange system. AMIS programme activity areas include

- Coordinating databases with information on air quality issues in major and megacities;
- Acting as an information broker between countries;
- Providing and widely distributing technical documents on air quality management;
- Publishing and widely distributing Annual Trend Reviews on air pollutant concentrations;
- Providing training courses with respect to air quality monitoring and management;
- Running Regional Collaborative Centres to support data transfer activities, perform training courses and implement twinning projects.

Other AMIS databases which are being planned or developed:

Characterisation of emissions of major and megacities;
Reference to other air quality databases;
Monitoring devices and address of manufacturers;
Addresses of training institutions;
Use and accessibility of dispersion models including information on where to access these models;
Control action and magnitude of their costs;
Adverse effects on air pollution on health and magnitude of their costs.

AMIS is a set of user friendly MSACCESS based databases. A core database contains summary statistics of air pollution data like annual means, 95-percentiles, and the number of days on which WHO guidelines are exceeded. Any compound for which WHO air quality guidelines exist can be entered into the open-ended database. In the existing version data (mostly from 1986 to 1996) from about 100 cities in 40 countries are represented. Moreover, a report of the data will be produced. Other realised databases include a database on air quality management capabilities and procedures of cities, a noise level database and an indoor air database.

All these items will be made available to AMIS participants and also distributed to interested non profit organisations free of charge.

Data for this and other AMIS databases which are being planned (see box) will be routinely collected via WHO Regional Offices and AMIS Regional Collaborating Centres. For the core database it is intended to increase the number of contributing cities 300 by end of the millennium. Cities can easily compare their data with the data of all other participants in the system Another database that has been realised is the database on air quality standards. Standards from about fifty countries are incorporated and can be seen in comparison with the WHO air quality guidelines. A database with the names and addresses of the AMIS focal points allows direct communication between the participants. An updated CD ROM with air pollutant concentration data from more than 100 cities was published in 1998 and is being widely distributed. Other information such as the air quality guidelines and the noise guidelines are also on this CD ROM. It is planned to bring the databases to the Internet accessible through the WHO, ASMA, and USEPA homepages.