## DRAFT WILDFIRE SMOKE PUBLIC HEALTH ADVISORY
## STAGE 1: ALERT
## $PM_{10}$ > 100 $\mu g/m^3$ or $PM_{2.5}$ > 85 $\mu g/m^3$, 4 HR AVERAGE

FOR IMMEDIATE RELEASE:

SMOKE FROM FOREST FIRES IN THE AREA HAVE REACHED LEVELS THAT MAY AFFECT YOUR HEALTH. AIR POLLUTION MONITORING INFORMATION FROM (LOCATION) INDICATES THAT SMOKE LEVELS DURING THE PAST 4 HOURS HAVE REACHED A STAGE I ALERT LEVEL. FIRE FIGHTERS EXPECT SMOKE LEVELS IN THE AREA TO REMAIN HIGH DURING THE NEXT HOURS.

ALL PERSONS WITH LUNG OR HEART DISEASES SUCH AS ASTHMA, BRONCHITIS OR ANGINA SHOULD STAY INDOORS WITH YOUR DOORS AND WINDOWS CLOSED. AVOID EXERTION AND EXPOSURE TO TOBACCO SMOKE. BE SURE YOU HAVE AT LEAST A 5 DAY SUPPLY OF YOUR MEDICATION.

SPORTS PRACTICES SHOULD BE CANCELLED. EVERYONE SHOULD AVOID VIGOROUS OUTDOOR ACTIVITY.

IF YOU HAVE REPEATED COUGHING, HEADACHES, CHEST TIGHTNESS OR PAIN, WHEEZING OR WHISTLING IN YOUR CHEST, DIFFICULTY BREATHING OR NAUSEA, CONTACT YOUR HEALTH CARE PROVIDER.

FOR MORE INFORMATION, CONTACT THE _____
(AGENCY NAME)

AT_____ (PHONE NUMBER).

ISSUED AT: _____ TIME _____ DATE _____

## DRAFT WILDFIRE SMOKE PUBLIC HEALTH ADVISORY
## STAGE 2: WARNING
## $PM_{10}$ > 150 $\mu g/m^3$ or $PM_{2.5}$ > 1 3 0 $\mu g/m^3$, 4 HR AVERAGE

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FOR IMMEDIATE RELEASE:

SMOKE FROM FOREST FIRES IN THE AREA HAVE REACHED LEVELS THAT MAY AFFECT YOUR HEALTH. AIR POLLUTION MONITORING INFORMATION FROM (LOCATION) INDICATES THAT SMOKE LEVELS DURING THE PAST 4 HOURS HAVE REACHED THE LEVEL 2 WARNING LEVEL. FIRE FIGHTERS EXPECT SMOKE LEVELS IN THE AREA TO REMAIN HIGH DURING THE NEXT HOURS.

ALL PERSONS WITH LUNG OR HEART DISEASES SUCH AS ASTHMA, BRONCHITIS OR ANGINA SHOULD EVACUATE TO A SMOKE-FREE AREA, PROVIDED YOU CAN DO SO SAFELY. IF YOU CHOOSE NOT TO LEAVE THE AREA, YOU SHOULD TEMPORARILY MOVE TO _____ (NAME OF FACILITY) LOCATED AT _____(ADDRESS) WHERE THE AIR IS SMOKE-FREE. HEALTH CARE PROVIDERS ARE THERE TO HELP YOU.

ALL OTHERS SHOULD STAY INDOORS WITH YOUR DOORS AND WINDOWS CLOSED. AVOID EXERTION AND EXPOSURE TO TOBACCO SMOKE. IF YOU HAVE REPEATED COUGHING, HEADACHES, CHEST TIGHTNESS OR PAIN, WHEEZING OR WHISTLING IN YOUR CHEST, DIFFICULTY BREATHING OR NAUSEA, CONTACT YOUR HEALTH CARE PROVIDER.

SPORTS PRACTICES SHOULD BE CANCELLED. EVERYONE SHOULD AVOID VIGOROUS OUTDOOR ACTIVITY.

FOR MORE INFORMATION, CONTACT THE _____
(AGENCY NAME)

AT _____ (PHONE NUMBER).

OUR NEXT UPDATE ON SMOKE CONDITIONS WILL BE IN _____ MINUTES.

ISSUED AT: _____ TIME _____ DATE _____

## DRAFT WILDFIRE SMOKE PUBLIC HEALTH ADVISORY
## STAGE 3: EMERGENCY
## $PM_{10}$ > 400 $\mu g/m^3$ or $PM_{2.5}$> 340 $\mu g/m^3$, 1 HR AVERAGE

FOR IMMEDIATE RELEASE:

SMOKE FROM FOREST FIRES IN THE AREA HAVE REACHED LEVELS THAT WILL AFFECT YOUR HEALTH. AIR POLLUTION MONITORING INFORMATION FROM _____. (LOCATION) INDICATES THAT SMOKE LEVELS DURING THE PAST HOUR HAVE REACHED THE STAGE 3 EMERGENCY LEVEL. FIRE FIGHTERS EXPECT SMOKE LEVELS IN THE AREA TO REMAIN HIGH DURING THE NEXT HOURS.

PERSONS WITH LUNG OR HEART DISEASES SUCH AS ASTHMA, BRONCHITIS OR ANGINA SHOULD STAY INDOORS WITH YOUR DOORS AND WINDOWS CLOSED. IF YOU MUST GO OUTSIDE, AVOID EXERTION. SPORT SHOULD BE CANCELLED. PERSONS EXPERIENCING SHORTNESS OF BREATH, COUGH, CHEST PAIN, NAUSEA OR ANGINA SHOULD CONTACT THEIR HEALTH CARE PROVIDER.

PERSONS BEING AFFECTED BY THE SMOKE SHOULD IMMEDIATELY MOVE TO _____ (NAME OF FACILITY) LOCATED AT (ADDRESS)_____ WHERE THE AIR IS SMOKE-FREE. HEALTH CARE PROVIDERS ARE THERE TO HELP YOU. YOU WILL BE ABLE TO RETURN HOME AS SOON AS THE SMOKE CONDITIONS ALLOW.

FOR MORE INFORMATION, CONTACT THE _____
(AGENCY NAME)
AT _____ (PHONE NUMBER).

OUR NEXT SMOKE UPDATE WILL BE IN _____ MINUTES

ISSUED AT: _____ TIME _____ DATE _____

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## Table 1
## Components, key elements and examples of a wildland fire prevention programme

| Components | Key elements | Examples |
|---|---|---|
| Engineering | Separating heat sources from fuels; reducing or eliminating fuels when heat sources must remain; and shielding fuels from heat sources to prevent contact. | Creating and maintaining fuel breaks; clearance around structures and power lines; design and installation of spark arresters; and the development of fire codes and regulations. |
| Education | Informing the public of wildland fire prevention practices; changing attitudes and behaviour; and creating an awareness of fire prevention. | School and civic group programmes; person-to-person contacts; parades, exhibits and displays; posters and billboards; and public service contacts on radio or TV. |
| Enforcement | Compliance with local, state and federal fire codes and regulations; fire cause determination; and law enforcement action. | Inspection for compliance with fire safety laws and regulations; investigation of fire cause; red flag patrolling and closure of areas; and law enforcement and court action. |

## Table 2
## Guidelines for width of fire line

| Fuel type | Width of cleared area (m) | Width in mineral soil (m) |
|---|---|---|
| Grass | 0.61 to 0.92 | 0.61 to 0.92 |
| Medium brush | 1.22 to 1.83 | 1.83 to 2.44 |
| Heavy brush | 2.75 | 0.31 to 0.61 |
| Very heavy brush or logging slash | 3.66 | 0.92 |
| Timber | 6.1 | 0.92 |

## Table 3
## Emission factors for particulate matter as a function of fire behaviour

| | | Ton[1] |
|---|---|---|
| Grass | Flaming dominates | 7.5 |
| Understory vegetation/litter | Flaming w/light smouldering[2] | 12.5 |
| | Flaming w/moderate smouldering[3] | 15 |
| | Flaming w/moderate smouldering[4] | 37.5 |
| Broadcast slash | Flaming dominates 10 | |
| | Flaming w/smouldering component | 20 |
| Piled and windowed slash | Flaming dominated | 12.5 |
| | Flaming w/moderate smouldering | 25 |
| Slash | Flaming w/heavy smouldering[5] | 7.5 |
| Brush fuels | Flaming dominates | 12.5 |
| | Flaming w/moderate smouldering | 25 |
| All fuels | Burning where smouldering dominates | 75 |

[1] g/kg of fuel burned on dry weight basis.
[2] backing fires or heading fires in light fuels without duff involvement.
[3] heading fires in litter fuels with heavy loading.
[4] fires in litter fuels with substantial duff consumption.
[5] soil free and very dry.
[6] heavy mineral soil component and/or high fuel moisture.

## Table 4
## Approximate relationship between wildfire smoke concentrations and visibility conditions

| $PM_{10}$ particulate matter ($\mu g/m^3$) | Visibility (km) |
|---|---|
| 100 | 6.0 |
| 200 | 3.0 |
| 400 | 1.5 |
| 600 | 1.0 |
| 800 | 0.7 |

**Figure 1**
**Stages of combustion**

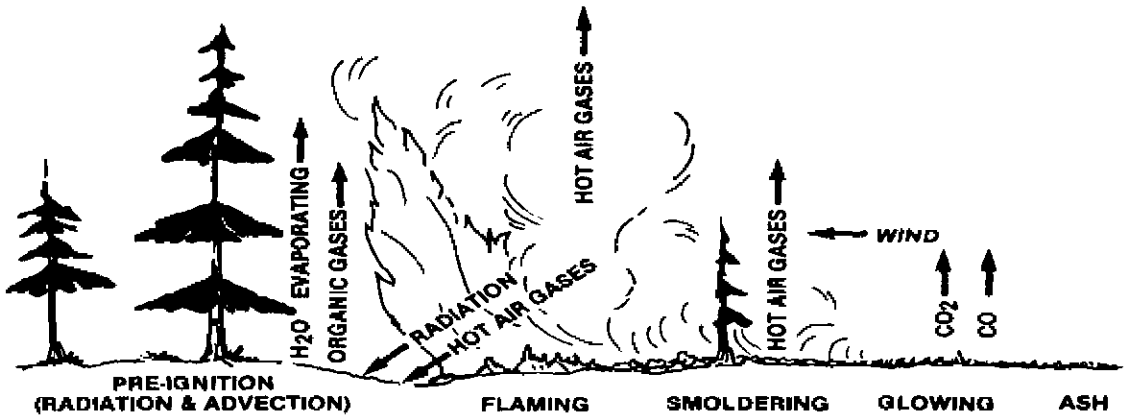


**Figure 2**
**Why a fire spread**

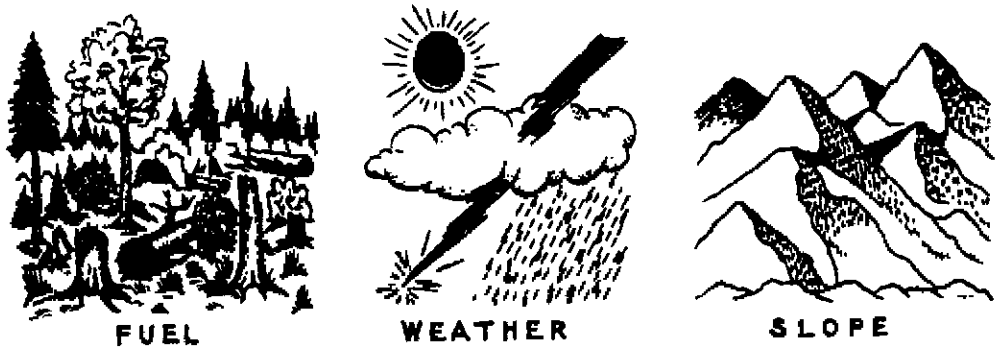

**Figure 3**
**The fire triangle**

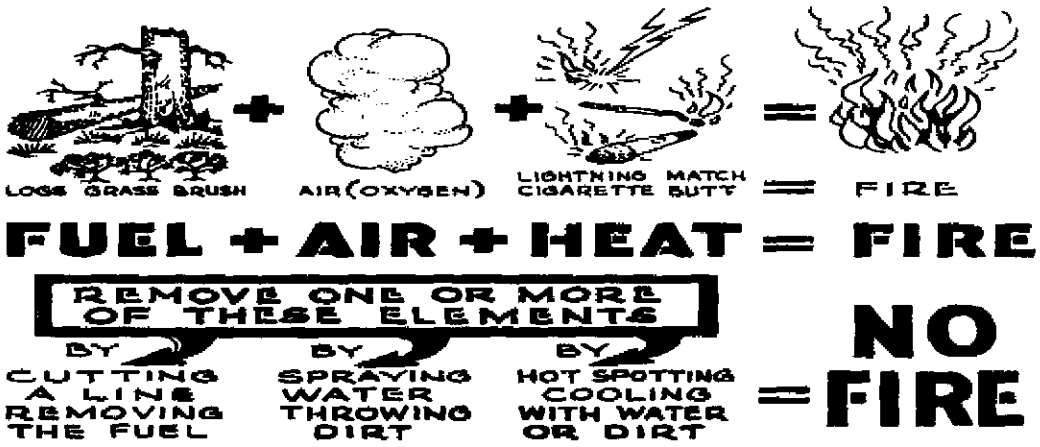


**Figure 4**
**Respirator Design**

**Mask** **Full face mask** **Half-face mask**

# PUBLIC INFORMATION AND MITIGATION MEASURES FOR A HAZE EPISODE: THE SINGAPORE EXPERIENCE

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## INTRODUCTION

During the 1997 regional smoke haze episode, the authorities in Singapore were inundated daily with enquiries from members of the public and the mass media on various haze-related issues. The environmental health questions posed included the state of air pollution, what the authorities were doing about the problem, what were the health and other effects, and what mitigation measures could be taken. The tremendous pressure for coordinated flow of timely information to the public enabled a more organised management system to emerge, and practical advice on mitigation measures such as the use of air cleaners and masks gave confidence to the public that the authorities were in control of the situation. Although the Singapore experience applies to an urban context and cannot be directly extrapolated to other countries, some of the lessons learnt could be useful. We present herein the country-level activities that can be undertaken in relation to information provision and mitigation measures during a haze emergency.

## INFORMATION TO THE PUBLIC

### Information on ambient air quality

Among the basic requirements in protecting the public health during a haze emergency is the provision of a reasonably 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 actions that need to be taken by the population to minimise damage to health. An air quality monitoring programme should be put in place as a primary activity to protect 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 policy decisions to be made to prevent air pollution episodes; and
- to assess the effectiveness of pollution control measures implemented to improve ambient air quality

The 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 against a serious air pollution event such as vegetation fire pollution.

*In Singapore, ambient air quality is monitored by an island-wide network of 15 stations. These stations are linked via the public telephone network to a central control station situated within the headquarters of the Ministry of the Environment. The main air pollutants monitored in Singapore are sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone and particulate matter less than 10 μm in aerodynamic diameter ($PM_{10}$). The monitoring of $PM_{2.5}$ has also been initiated at two separate stations in Singapore. Other environmental parameters such as humidity, temperature, wind speed and direction are measured at selected stations as well. The monitoring in Singapore uses the United States Environmental Protection Agency (USEPA)'s reference methods* (1).

Once the 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 which 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 is useful as it is accepted internationally and is based on extensive evidence of the health effects among the population due to various air pollutant components.

*In Singapore, the long-term goals of the World Health Organisation (WHO) and the primary air quality standards of the USEPA are used as the guidelines to assess the ambient air quality. The levels for some gaseous and particulate pollutants are given in Table 1 and 2. Singapore has also adopted the PSI method of reporting the daily pollutant measurements. Basically, the index is obtained by converting the pollutant concentration for five major air pollutants, ie, sulphur dioxide, particulate matter ($PM_{10}$), nitrogen dioxide, ozone and carbon monoxide, into a simple integer scale of 0 to 500. The highest value for any one of these five readings will be the PSI level for the day. The PSI reading is released to the public every day at 4.00 pm. The air quality is classified as "good" for PSI levels of 0-50; "moderate", 51-100; "unhealthy", 101-200; "very unhealthy", 201-300; and "hazardous", above 300* (1).

It should be noted that in the event of emergency due to vegetation fire, the health alert advisory given for pollution levels experienced over the last 24 hours as indicated by the PSI level may not be adequate to help the population react fast and modify their activities. It is important that pollution indices should not be overemphasized, and pollutant-specific information should also be reported. This is particularly important for $PM_{10}$, as current research as well as WHO air quality guidelines generally do not support the concept of a threshold or no-adverse effect level for particulate exposure (2-5). Index readings slightly below "unhealthy" levels, when based on $PM_{10}$ measurements, may provide a false sense of security. There is consistent evidence of short-term health impact of the haze below the USEPA $PM_{10}$ standard of 150 $\mu g/m^3$ from various studies (6-11). Modifications may need to be made by the government to the air quality reporting system to ensure more timely information on the pollution levels during vegetation fire and other serious pollution emergency.

Information on the pollution levels should be made through the broadcasting media together with appropriate health advisories.

**Information on national action**

A comprehensive haze action plan (HAP) should be developed to ensure a full preparedness of the population to the health impact of vegetation fire pollution, particularly the more vulnerable sections of the population such as the asthmatics, the elderly and children. The HAP must be widely publicized through the media before the occurrence of any vegetation fire pollution episode. This will enable the public to be familiar with tasks to be taken and modification to activities to be made at various air quality levels to reduce the health effects of the pollution. Based on the HAP, government departments should draw up operating procedures to be adopted in the event of a vegetation fire pollution emergency. This will ensure that the population would know the changes made to public services and facilities in accordance with the prevailing vegetation fire pollution emergency situation.

*In Singapore, there is a multi-agency Haze Task Force, chaired and coordinated by the Ministry of the Environment, which is responsible for the national HAP. The aim of the national HAP is to ensure full preparedness to ameliorate the impact of haze on the health and well-being of the general public, in particular, the more vulnerable sections of the population such as the young and elderly. The HAP is publicised widely through the media and is posted on the internet at http://www4.gov.sg/env/pi/psi/index.html. Under the HAP, detailed tasks have been formulated for activation at different pollution levels. A summary of the HAP is given in Table 3. The Ministry of Health has also lined up contingency measures to deal with forest fire pollution emergency in line with the PSI levels. Some of the actions include:*

*a) 24-hour PSI level between 51 and 200:*

- *All necessary facilities will be made adequately available to cope with the anticipated increase in demand for services. Additional relevant facilities at polyclinics and Accident & Emergency Departments will be identified and activated.*

- *Suppliers of respirator masks will be alerted to ensure adequate stocks are made available at retail pharmacies, hospitals and polyclinics.*

- *Toll-free call-in lines will be provided to provide heath-related enquiries to supplement the Ministry of the Environment's Haze Hotline.*

*b) 24-hour PSI level between 201 and 400:*

- *Additional staff will be deployed to government polyclinics and Accident & Emergency Departments of public hospitals if attendances reach an identified critical level. Polyclinic operating hours will be extended if the need arises.*

- *Respirator masks will be issued to field health workers.*

- *Hospitals will be alerted of impending worsening conditions, and elective admissions and surgery may be cancelled.*

**Information on health effects and cautionary statements**

It is imperative that the authorities monitor the population's health during a vegetation 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. Health data during non-haze periods (normal levels of pollution) should also be monitored to provide the baseline information. In the longer term, the information gathered would enable the authorities to refine their national action plan.

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

Concern about frequently asked questions such as the safety of food and potable water exposed to smoke haze for indefinite periods 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.

*In Singapore, a national sentinel health surveillance system will undertake close monitoring of the following haze-related conditions:*

*i) Attendance at government polyclinics for conjunctivitis, acute upper respiratory tract infection (including influenza), allergic rhinitis, acute bronchitis, asthma (acute and chronic), eczema (including contact dermatitis), exacerbation of chronic obstructive pulmonary diseases, exacerbation of ischaemic heart disease (IHD);*

*ii) Attendances for the following haze-related conditions at public hospitals and Accident & Emergency Departments: IHD, pneumonia, asthma, bronchitis, emphysema, acute conjunctivitis;*

*iii) Admissions into public hospitals for the following conditions: IHD, pneumonia, asthma, bronchitis, emphysema and exacerbation of obstructive lung diseases; and*

*iv) Mortality from IHD, pneumonia, asthma, bronchitis, emphysema and other chronic obstructive pulmonary diseases.*

*A summary of the known general health effects and cautionary statements at different levels of air pollution is given in the HAP in Table 2.*

## MITIGATION MEASURES

### Remaining indoors

For non air-conditioned homes or buildings, only limited protection from fine particulate 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 (12). 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 air changes per hour, but vary by season and specific geographical location (13). 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/hr, while non air-conditioned homes had rates of 1.2/hr, 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, by weatherizing in cold seasons and by installing air conditioners for hot seasons to reduce the use of open windows (13). 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 actions to reduce the infiltration of outdoor air. Air conditioners, especially those with efficient filters, will substantially reduce indoor particle levels. 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.

**Personal lifestyle modifications**

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

**Use of air cleaners**

Portable air cleaners are effective at reducing indoor particle levels, provided the specific cleaner is adequately matched to the indoor environment in which it is placed. 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.

Air cleaners can be used as a mitigation measure against pollution due to forest fires and information on their effectiveness should be publicized. Portable air cleaners are compact, stand-alone appliances designed to lower the particulate 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 an 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 which the specific cleaner can filter. By matching a device's CADR to the specific 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.

*In Singapore, the Ministry of the Environment has carried out evaluation tests on air cleaners and given appropriate practical advice to schools, building owners and the general public on the installation of air cleaners in buildings. Press statements have been made advising the public to consider fitting their homes and offices with air filters to minimise the impact of the vegetation fire pollution. Results of evaluation tests are released to the media together with information on the CADR given by overseas testing agencies. A list of portable air cleaners available in the market that passed the evaluation test have been made available to the public. For buildings with central air conditioning systems, special devices are recommended to be added to the air handling unit to keep the particulate levels to acceptable levels. These devices include electrostatic precipitators, high-efficiency media filters and medium-efficiency media filters. Schools, child-care centres, old folk homes, hospitals and hospices are also urged to install these air filters to minimise risks to susceptible individuals and children.*

## Use of masks

While dust masks are relatively inexpensive and may be distributed to a large segment of the population, their effectiveness for general population use must be questioned. Despite this reservation, it is likely that the benefits (even partial) of wearing dust masks will outweigh the physiological and economic costs. Accordingly, in the absence of other mitigation techniques, the use of dust masks is warranted. Education of the population regarding specific mask types to purchase, how to wear them and when to replace them will increase their effectiveness, as will the development of new masks designed for general population use.

The public should be advised on the use of masks, particularly when they are involved in outdoor activities during periods of air pollution. Advice should also be given to the public on the relative utility of masks in keeping out particulates from the smoke haze. These include the proper use and selection of appropriate masks from among those available in the market.

Basically, there are two categories of masks: surgical/similar masks and respirator masks. The public should be advised that surgical/similar masks are not too useful in preventing the inhalation of fine particles 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 forest 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 cardiorespiratory 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 without undue breathing resistance to an average healthy adult. At higher efficiencies, breathing resistance increases and the user will experience more discomfort.

*In Singapore, the general public has been advised that the use of masks is unnecessary when the air quality remains in the good to*

*moderate region. During intense haze (eg, PSI over 200), the public should avoid outdoor activity rather than put on a mask and stay outdoors for prolonged periods. However, for those who could not 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, ie, those designed for fine particle removal.*

## Outdoor precautionary measures

Precautionary measures should be taken to safeguard the health and safety of workers who must continue to perform outdoor work. Appropriate respirators, if necessary, should be provided by employers to ensure workers are well-protected.

*In Singapore, the Ministry of Manpower advises employers to ensure that appropriate precautionary measures are taken to safeguard the health and safety of their workers, especially those who have to work during the haze. Employers should provide suitable respirators to workers who need to use them for outdoor work as part of the safety and health requirements for the protection of the health of their workers. At PSI level <200, it is not necessary for normal healthy workers to use respirators when working outdoors. Outdoor workers are advised to use respirators when the PSI levels exceed 200 and they must use respirators when the PSI levels exceed 300.*

*Workers with existing heart or respiratory ailments are more susceptible to the effects of the haze. When the PSI levels exceed 100, outdoor workers with existing heart or respiratory ailments are 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. At higher PSI levels (>200), they should be deployed to do indoor work which is not physically strenuous. When the PSI levels exceed 300, outdoor work should not be carried out unless workers are adequately protected (eg, with suitable respirators). Those who have difficulty with using respirators and working outdoors should be deployed to do indoor work. In addition, outdoor work which involves strenuous physical activity should be minimised. For safety reasons, when the PSI levels exceed 300, outdoor work with a risk of*

*falling from heights should not be allowed (unless precautions have been taken to reduce this risk). When the PSI levels exceed 400, no outdoor work should be allowed except for emergency and essential services.*

## CONCLUSION

The coordinated flow of information to the public and practical advice on mitigation measures such as the use of air cleaners and masks is crucial in the management of a smoke haze emergency. In Singapore, the main emphasis in the 1997 smoke haze episode has been on strengthening and fine-tuning the provision of timely information on the severity of air pollution and appropriate health advisories for members of the public.

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## Table 1
## USEPA primary air quality standards

| Parameter | Averaging Time | Concentration ($\mu g/m^3$) | Method |
|---|---|---|---|
| Gaseous pollutants | | | |
| Sulphur dioxide | Annual mean | 80 | Pararos-aniline |
| | 24 hour | 365 | pulsed fluorescence |
| Carbon monoxide | 8 hours | 10,000 | Non- dispersive |
| | 1 hour | 40,000 | infrared spectrometry |
| Nitrogen dioxide | Annual mean | 100 | Chemiluminescence |
| Ozone | 1 hour | 120 | Ultraviolet photometry |
| Particulate pollutants | | | |
| Respirable suspended | Annual mean | 50 | High volume |
| particles | 24 hours | 150 | Sampling |
| Lead | 3 months | 1.5 | Atomic absorption Spectroscopy |

## Table 2
## World Health Organization long-term goals (14-16)

| Parameter | Averaging Time | Concentration ($\mu g/m^3$) |
|---|---|---|
| Gaseous pollutants | | |
| Sulphur dioxide | Annual mean | 50 |
| | 24 hours | 125 |
| Carbon monoxide | 8 hours | 10,000 |
| | 1 hour | 30,000 |
| Nitrogen dioxide | Annual mean | 40 |
| | 1 hour | 200 |
| Ozone | 8 hours | 120 |
| Particulate pollutants | | |
| TSP | 24 hours | 120 |
| Respirable | 24 hours | 70 |
| Lead | 1 year | 0.5 |

## Table 3
## National haze action plan (Singapore) (17)

| Index value | PSI descriptor | General health effects | Cautionary statements | Detailed tasks |
|---|---|---|---|---|
| Up to 50 | Good | None | None required | Provide hourly PSI updates to the media.<br><br>Provide PSI updates to other ministries and agencies so that they can get ready to implement their Standard Operating Procedures (SOPs).<br><br>Liaise with industries with fuel-burning equipment on the need to cut down emissions.<br><br>Liaise with major vehicle fleet owners on measures to minimise emissions |
| 51 to 100 | Moderate | Few or none for the general population | None required | Same as above |

Note: PSI = Pollutant Standards Index; NHTF = National Haze Task Force

## Table 3
## National haze action plan (Singapore) (cont'd)

| Index value | PSI descriptor | General health effects | Cautionary statements | Detailed tasks |
|---|---|---|---|---|
| 101 to 200 | Unhealthy | Mild aggravation of symptoms among susceptible people with irritation symptoms in the healthy population | Persons with existing heart or respiratory ailments should reduce physical exertion and outdoor activity. General population should reduce vigorous outdoor activity. | Provide hourly PSI updates and health advisories to the media.<br><br>Provide PSI updates to the other ministries and agencies.<br><br>Liaise with industries with fuel-burning equipment on the need to cut down emissions.<br><br>Liaise with major vehicle fleet owners on measures to minimise emissions<br><br>Activate Haze Info-line (1800-7319222) to provide information and to answer queries from the public.<br><br>When 24-hour PSI stays above 100 for more than 48 hours, NHTF to meet as often as required to co-ordinate implementation of the SOPs of individual ministries and agencies.<br><br>NHTF to hold press briefings |

Note: PSI = Pollutant Standards Index; NHTF = National Haze Task Force

## Table 3
## National haze action plan (Singapore) (cont'd)

| Index value | PSI descriptor | General health effects | Cautionary statements | Detailed tasks |
|---|---|---|---|---|
| 201 to 300 | Very Unhealthy | Significant aggravation of symptoms and decreased tolerance in persons with heart or lung disease; widespread symptoms in healthy population | Elderly persons with existing heart or lung disease should stay indoors and reduce physical activity. General population should avoid vigorous outdoor activity | Provide hourly PSI updates and health advisories to the media.<br><br>Provide PSI updates to the other ministries and agencies.<br><br>Activate Haze Info-line (1800-7319222) to provide information and to answer queries from the public .<br><br>When 24-hour PSI stays above 100 for more than 48 hours, NHTF to meet as often as required to co-ordinate implementation of the SOPs of individual ministries and agencies.<br><br>NHTF to hold press briefings |

Note: PSI = Pollutant Standards Index; NHTF = National Haze Task Force

## Table 3
## National haze action plan (Singapore) (cont'd)

| Index value | PSI descriptor | General health effects | Cautionary statements | Detailed tasks |
|---|---|---|---|---|
| 301 to 400 | Hazardous | Early onset of certain diseases in addition to symptoms and decreased exercise tolerance in healthy persons | Elderly, children and persons with existing diseases should stay indoors and avoid physical exertion. General population should avoid unnecessary outdoor activity | Provide hourly PSI updates and health advisories to the media.<br><br>Provide PSI updates to the other ministries and agencies.<br><br>Inform industries with fuel burning equipment and major vehicle fleet owners to cut down emissions.<br><br>Advise motorists through media to reduce use of private motor vehicles.<br><br>When 24-hour PSI > 250, NHTF to meet to reaffirm measures with regard to advising industries, schools and construction sites on outdoor work, closure of schools, stoppage of outdoor functions and sports activities.<br><br>Provide regular updates on the haze situation to the public.<br><br>NHTF to hold press briefings |

Note: PSI = Pollutant Standards Index; NHTF = National Haze Task Force

## Table 3
## National haze action plan (Singapore) (cont'd)

| Index value | PSI descriptor | General health effects | Cautionary statements | Detailed tasks |
|---|---|---|---|---|
| Over 400 | Hazardous | PSI levels above 400 may be life-threatening to ill and elderly persons. Healthy people may experience adverse symptoms that affect normal activity | All persons should remain indoors, keeping windows and doors closed, and minimise physical exertion | Provide hourly PSI updates and health advisories to the media.<br><br>Provide PSI updates to the other ministries and agencies.<br><br>NHTF to convene urgent meeting to decide:<br>1. closure of schools.<br>2. closure of childcare centres.<br>3. closure of sports facilities and stoppage of sports activities.<br>4. stoppage of outdoor work by industries, construction sites, etc., and/or the use of respirators by workers doing outdoor work<br><br>When 24-hour PSI > 350, NHTF to deliberate on the need to declare a haze emergency if PSI exceeds 400.<br><br>Proclaim a haze emergency if the government so decides.<br><br>Regular public announcements to be made. NHTF to hold press briefings |

Note: PSI = Pollutant Standards Index; NHTF = National Haze Task Force

The index value refers to the 24-hour Pollutant Standards Index (PSI) value and not to the 3-hour PSI value. Only the 24-hour PSI value is correlated to the health effects outlined.

# APPLICATION OF APPROPRIATE SHORT-TERM AIR QUALITY GUIDELINES

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## INTRODUCTION

The primary purpose of ambient air quality guidelines is the protection of public health. Guidelines provide exposure levels considered appropriate and acceptable for the safeguarding of health. The pollutant levels recommended are values below which exposure, for lifetime or for a given period of time, does not constitute a significant health risk. The guidelines are usually health consideration based on the latest state of scientific knowledge, although ecological concerns may be included. Local authorities need to take other factors into account when making risk assessment and risk management decisions, including prevailing exposure levels, technical feasibility, source control measures, abatement strategies, as well as social, economic, and cultural conditions (1).

## DUAL ROLE OF SHORT-TERM AIR QUALITY GUIDELINES AS RISK MANAGEMENT TOOL

During short-term air quality deterioration such as a forest-fire air pollution episode, air quality guidelines alone is inadequate and ineffective. There is a need for immediate actions to mitigate untoward health impacts to the public. In this situation, guidelines should also serve as a tool for public information and recommended actions. It should link

air quality or exposure levels with public precautionary measures and health risk communication activity. Different levels of exposure, health effects (e.g. mild, moderate, severe) and action to be taken should be established for practical purpose of field operations, with consideration of non-health factors referred to earlier.

For the linkage between air quality with public information and recommended actions, two examples of air quality management guidelines proposed and adopted in Europe and the US demonstrate this approach.

First, "air pollution alert system" is a guide for action when peak exposures to urban winter- or summer-type smog occurs in a number of countries in Europe (2). In general, when effects are expected to be mild, no action other than 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 could be recommended on a voluntary basis, and emergency short-term measures such as closing of schools or limiting of traffic could be considered.

The US Environmental Protection Agency (EPA) and several agencies developed an urban air quality composite index, called pollutant standards index (PSI), based on the integrated ambient measures of five major criteria pollutants (3). The EPA 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 if air pollution levels rise into the unhealthful range (Table 1). PSI levels above 100 may trigger health advisories by State or local officials. The 200 level is likely to trigger an "Alert" stage, in which some activities such as incinerator use or open burning might be restricted. A level of 300 on the PSI will trigger a "Warning", which is likely to prohibit the use of incinerators, severely curtail power plant operations, cut back operations at specified manufacturing facilities, and require the public to limit driving by using car pools and public transportation. A PSI level of 400 or above would constitute an "Emergency", and would require a cessation of most industrial and commercial activities, plus a prohibition of almost all private use of motor vehicles. In terms of particulate matter equal to or smaller

air quality or exposure levels with public precautionary measures and health risk communication activity. Different levels of exposure, health effects (e.g. mild, moderate, severe) and action to be taken should be established for practical purpose of field operations, with consideration of non-health factors referred to earlier.

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than 10 μm ($PM_{10}$), the EPA is required to issue a public alert when the levels on a 24-hour average reach 350 $\mu g/m^3$, a public warning when the levels reach 420 $\mu g/m^3$, and a declaration of public emergency at the level of 500 $\mu g/m^3$.

Another example from the US comes from the recent guidelines of the wildfire emergency action plan of the Western States Air Resources Council (4, 5). Details are as follows.

*Stage 1, Alert: $PM_{10}$ concentrations of greater than 100 $\mu g/m^3$ or $PM_{2.5}$ concentrations of 85 $\mu g/m^3$, 4-hour average*

*Action:* All individuals with pre-existing lung or heart disease should try to remain indoors with door and windows closed, and 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 5-day supply available. 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 presence of any of the following symptoms: headache, repeated coughing, chest tightness or pain, wheezing in the chest, excessive phlegm production, difficulty in breathing and nausea. All individuals should avoid vigorous outdoor activity.

*Stage 2, Warning: $PM_{10}$ concentrations of greater than 150 $\mu g/m^3$ or $PM_{2.5}$ concentrations of 130 $\mu g/m^3$, 4-hour average*

*Action:* All of the stage 1 warnings also apply to stage 2. In addition, individuals with chronic respiratory and cardiac conditions should be advised to evacuate to 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 specially 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 and other respiratory irritants.

*Stage 3, Emergency: Heavy smoke conditions, $PM_{10}$ concentrations exceeding 400 μg/m³ or $PM_{2.5}$ concentrations exceeding 340 μg/m³, 1-hour average*

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

*Re-entry*

Action: After the wildfire has been contained, an "all-clear" declaration has been issued based on a forecast of smoke clearance, and public health alerts have been cancelled, affected persons can return to the community.

## APPLICABILITY OF WHO AIR QUALITY GUIDELINES

Smoke from forest fires consists mainly of fine particles in the respirable range which is conducive to long-range and transboundary transport (6), resulting in widespread short-term increase in particulate matter levels all over the affected areas.

Special consideration should be given to particulate matter when making appropriate short-term air quality guidelines. New scientific data on the epidemiological assessment of exposure to particles do not support the establishment of a level below which no effects would be expected (7,8). Instead of the usual threshold levels or guideline values, local authorities are now guided by exposure-effect information of major health impacts from short- and long-term exposure to various levels of particles.

However, for practical purpose, short-term forest fires air quality guidelines can be developed using the same general approach as the

WHO's guidelines (1) in combination with risk management explained above. There may be questions regarding the averaging time and the appropriate unit that better represent air quality or exposure levels. The averaging time used and reported in the guidelines should be 24-hour average, which conforms to the available evidence of short-term effects using daily exposure in time-series studies. As fine particulate matter is the main culprit, the concentrations or actual levels of particles should be used in the guidelines to directly reflect their relationship with health effects, instead of a composite index which requires additional numerical calculation and may cause differences between two computation schemes.

In practice, three levels of $PM_{10}$ relating to the corresponding health effects, (mild, moderate and severe) and the corresponding preventive or mitigating activities (alert, warning and emergency, respectively) may be established. Available information on the dose-response relationship of particles will form the basis of demarcating these intervals based on scientific judgement.

## REFERENCES


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## Table 1
## General health effects and precautionary steps associated with levels of PSI (3)

| Index value | Descriptor | General health effects | Cautionary statement |
|---|---|---|---|
| Up to <50 | Good | None | None |
| 50 to 100 | Moderate | Few or none for the general population | None |
| 100 to <200 | Unhealthful | Mild aggravation of symptoms among susceptible people, with irritation symptoms in the healthy population | Persons with existing heart or respiratory ailments should reduce physical exertion and outdoor activity. General population should avoid vigorous outdoor activity. |
| 200 to 300 | Very Unhealthful | Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease; widespread symptoms in the healthy population. | Elderly and persons with existing heart or lung disease should stay indoors and reduce physical activity. General population should avoid vigorous outdoor activity. |
| Over 300 | Hazardous | Early onset of certain diseases in addition to significant aggravation of symptoms and decreased exercise tolerance in healthy persons. At PSI levels above 400, premature death of ill and elderly persons may result. Healthy people experience adverse symptoms that affects normal activity | Elderly and persons with existing diseases should stay indoors and avoid physical exertion. At PSI above 400, general population should avoid outdoor activity. Everyone should remain indoors, keep windows and doors closed and minimize physical exertion. |