They will then be called upon to review or to formulate the forest fire prevention programmes. The purpose is to adapt them according to new technical contributions, aimed at obtaining a strategic plan as the final product. Contributions from other agencies should also be incorporated. These agencies will be summoned in the implementation stage.

It would be desirable to organise inter-institutional workshops on strategic planning or other related methodologies. These will allow exchange and development of specific commitments; i.e. training plans, on-site work, drills, information exchange and establishment of communication systems. A greater commitment by all the participating institutions on the actions to be taken can be achieved, thus clearly establishing the role that each one must fulfill in case of an incident of this nature.

These working activities will permit specific tasks to be outlined, a plan of activities to be established, goals to be achieved, a timetable with exact dates designed, and the financial support of each activity to be determined.

Other relevant entities

Once the strategic plan has been established, and to further improve on it, it is suggested that other public and private institutions be called upon at another stage to review the work plan. These new entities include:

- universities, [schools of medicine; centres of environmental studies (air pollution analytical capacity)]; institutes for natural and forest resources; meteorological services (monitoring systems, meteorological variations, aerial and satellite information);
- private business associations linked to the forest or agriculture;
- aerophotometry services (air force)
- public security institutions (police); and
- armed forces (army and air force).

More information on the data collected as well aptitudes, functions and resources of these entities may be obtained through questionnaires.

Replication of the strategic plan at regional and local levels

Once the preparation of the strategic plan has been concluded by the national entities, the authority will have to instruct those in the regional and local levels to repeat this work in their respective territorial area. An adequate and permanent feedback of information on the progress and difficulties encountered should be maintained, together with an evaluation of the goals achieved.

HOW TO OBTAIN AND USE THE DATA FOR DECISION-MAKING IN THE ENVIRONMENTAL HEALTH ACTION PLANS

Available database

Once the strategic plan has been developed, it is necessary to design a database of the available technical information collected routinely by different entities. The objectives are: (i) to strengthen the forest fire prevention and control programmes; and (ii) to ensure that those responsible for dealing with this type of emergencies adopt the most appropriate measures on time. Based on the first stage of the preparation process of the plan, the technical agencies will then elaborate a database with the available information. Consultation will be made directly with other relevant entities, through a questionnaire sent by air mail or internet, and if the response is not timely, through direct inter-institutional interviews.

In designing the database, the following points will have to be specified:

- how is it compiled?
- with what periodicity and since when registries are available?

- is it possible to strengthen the frequency to comply with the needs of the plan?
- are there any requirements to improve them?
- is it subject to quality control systems? which particular ones?
- is the system going to be modified?

Analysis of the available information

Once this information is compiled, an evaluation must be made on:

- data quality: is it reliable?
- availability: is it of easy access and acceptable costs?
- frequency: is it appropriate to the needs of the plan?
- needs for complementing with other techniques, such as new air pollution monitoring systems, aerophotography, satellite images.

Once this review is done, procedures must be established to improve on such information which is inconvenient to obtain. Financial sources will also be searched. To compete with other new local projects, specific project design or international collaboration is necessary.

These plans are more likely to be accepted, if mechanisms for transferring or complementing information are proposed at national as well as international levels.

Generation of information systems for decision makers

With this background, and having developed the strategic plan, an information system will have to be organised so that the goals and objectives can be successfully met.

A surveillance programme for the environmental conditions that determine a greater forest fire hazards will have to be developed and periodically evaluated. It should be located close to thick forest areas in the direction of the prevailing winds. Topographical and climatological conditions that hinder the dispersion of air pollutants, fire hazards, such as prolonged summer season, sharp increases in temperatures or drought conditions, should be provided.

Air quality data

The air quality needs to be characterised, with periodic measurements for comparison at any time and according to the season of the year. In this case, it is desirable to have complete measurements during periods when forest fire hazard is greater (dry season of the year, smaller rainfall and higher temperatures).

Meterological and modelling data are required to analyse possibilities of increase or reduction in the intensity of pollution. These include winds, moisture, temperature, maximum impact points of pollution and pollutant dispersion conditions.

Information on forest fire hazards

Information on forest fire hazard levels should be obtained from state agencies in charge of preventing and fighting this type of incidents, as well as from private enterprises in forestry or agriculture.

Databases about the size of the forest or thicket close to populated centres which are in danger of forest fires should be elaborated.

In cases of declared fires, it is important to obtain aerial photographs and satellite images of the affected areas, to evaluate the magnitude and risks of the incidents, and to generate information for decision-makers.

Health data

Data on respiratory diseases in susceptible population (children) should be collected. It should be noted that while lower respiratory diseases are clinically more objective, respiratory diseases as a group are subject to a number of variables and their relationship to forest fires is difficult to evaluate. However, surveillance for respiratory diseases is useful to verify the damage or evaluate the impact on health in case the emergency continues. This is because the effect on health is observed days after the fire impacts on the air quality. To reduce costs, sentinel groups should be chosen, and information of the affected population from some representative health centres collected.

Data of population exposed to forest fire pollution

This type of information is useful to estimate the needs for support or reinforcement from health workers, or to plan resources in a better way regarding evacuation of the place (shelter planning). Data should be obtained on the extent of the population exposed to poor air quality, location, access roads, nearby health care services and population structure (sex, age, education level).

GUIDANCE ON MEASURES IN FOREST FIRE EMERGENCY CASES

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INTRODUCTION

This paper specifically addresses guidance for the prevention and control of wildland fires, the use of protective devices, and contingency planning. Before successful prevention or control of wildland fires can be achieved, basic knowledge of how fires burn and why fires spread is necessary.

PREVENTION AND CONTROL OF FIRES

How fires burn

When enough heat is applied to a fuel in the presence of air, combustion will result. Within a wildland fire, the processes of pyrolysis and combustion occur simultaneously.

Pyrolysis

When first heated, fuels produce water vapour and mostly noncombustible gases. Further heating initiates pyrolysis, the process by which heat causes chemical decomposition of fuel materials, and yielding organic vapours and charcoal. At about 204° C, significant amounts of combustible gases are generated. Also at this temperature, chemical reactions start to produce heat, causing pyrolysis to be self-sustaining if heat loss from the fuel is small. Peak production of combustible products occurs when the fuels are about 316° C.

Combustion

Combustion is the process during which combustible gases and charcoal combine with oxygen and release energy that was stored in the fuel as heat and light. Most observers of wildland fires can distinguish between flaming and smouldering combustion. Flaming combustion is characterized by the movement of visible flame through the fuel; smouldering combustion is a more general and loosely defined term associated with the die-down of a fire after the flame front has passed. It is more logical to consider fire in four phases: pre-ignition; flaming; smouldering; and glowing (Figure 1).

(i) Pre-ignition phase

In this phase, heat from an ignition source or the flaming front heats adjacent fuel elements. Water evaporates from fuels and the process of pyrolysis occurs, the heat-induced decomposition of organic compounds in fuels.

(ii) Flaming phase

Combustion gases and vapours resulting from pyroly[illegible] the fuels and mix with oxygen. Flaming occurs if they are [illegible] ignition point of 427°C to 482°C, if they come into contact with [illegible] hot enough to ignite them, such as flames from the fire front. The heat from the flaming reaction accelerates the rate of pyrolysis. This causes the release of greater quantities of combustible gases, which also oxidize, causing increased amounts of flaming.

(iii) Glowing phase

When a fire reaches the glowing phase, most of the volatile gases have been driven off. Oxygen comes into direct contact with the surface of the charred fuel. As the fuel oxidizes, it burns with a characteristic glow. This process continues until the temperature drops so low that combustion can no longer occur, or until all combustible materials gone.

(iv) Smouldering phase

Smouldering is a very smoky process occurring after the active flaming front has passed. Combustible gases are still being released by the process of pyrolysis, but the rate of release and the temperatures maintained are not high enough to maintain flaming combustion. Smouldering generally occurs in fuel beds with fine packed fuels and limited oxygen flow such as duff and punky wood. An ash layer on these fuel beds and on woody fuels can promote smouldering by separating the reaction zone from atmospheric oxygen.

Fire is basically a chemical reaction called rapid oxidation. Fire is produced only when heat, fuel, or oxygen are present in the right amounts. Fire cannot exist if any one of the elements is absent. The basic principle of fire control is to remove one or more of these elements in the quickest and most effective manner. Heat is the causal agent in the start of any fire. Once a fire has started, it can produce its own life-giving heat.

Why fires spread

The environment in which the fire is burning dictates how it will behave (Figure 2). The fire environment includes topography (slope, aspect, elevation, and configuration), fuels (type and characteristics, fuel moisture, fuel temperature, and fuel loading) and weather (air temperature, wind, relative humidity, air stability, clouds, and temperature inversions). Fire is influenced by many factors, most of which are subtle in their effect. The key to predicting fire behaviour is understanding how these factors combine and change burning patterns.

Prevention

There are three components of a wildland fire prevention programme: education, engineering, and enforcement. Key elements and examples are given in Table 1.

The purpose of a fire prevention programme is to eliminate or reduce risk (fire cause) and hazards (where and what it burns). There are several things that can be done to prevent fire in the wildlands. The first step in developing a fire prevention plan is to determine what the specific risks and hazards are. In some areas, the predominant cause is debris burning or equipment use; in other areas, it may be lightning or arson. Once it has been determined what are the causes of the fires, and in which fuels they have started, a plan to reduce these incidents should be developed. If the predominant cause is debris burning, a campaign targeting at those who are doing the burning should be started. The damage caused by these fires and the cost of putting them out should be pointed out. Safe burning should also be encouraged.

If the cause is logging or farming activities, these causes can be reduced by education of the workers, by installation of spark arrestor on machinery, or by restricting the hours of work during periods of high fire danger. The hazard may also be reduced by having fuel breaks constructed around operational areas or along roads.

The key to prevention is working with people. Education will go a long way, but if the local laws prohibit these types of fires, start prosecuting offenders. Law enforcement is the last element of prevention. It should only be used when everything else fails.

There are a number of reference materials that provide excellent guides to developing a fire prevention programme (1-3).

Control

To "control" a fire, the "fire triangle" must be broken (Figure 3). Water, chemicals or dirt serve to cool or smother the fire; a fire line can be cut with hand tools or equipment; and one can use the fire itself. The method or methods chosen will depend on the type of fuel, the fire behaviour, the terrain, and the firefighting resources that are available.

Use of water

Water cools the fire, breaking the heat side of the fire triangle. It can also dilute the oxygen side of the fire triangle when water vapour is created. Water, however, will be most effective if applied as part of an overall strategy that includes a fire line cut to mineral soil. A wet line as the final control line should never be considered. One volume of water will cool 300 volumes of burning fuel, if applied properly.

Use of chemicals

Water is a very effective fire-suppressing agent. However, water with a suppressant added can increase its effectiveness by a factor of 10. Suppressant is a substance that extinguishes the flaming and glowing phases of combustion by direct application to burning fuels. This is accomplished by coating and cooling the burning fuels. The following are examples of suppressants.

(i) *Wetting agents* can be added to water to reduce the surface tension of water and increase penetration and spreading capabilities. This is very effective during mop up. It is ineffective once the water has evaporated.

(ii) *Class A foams* are also very effective in controlling wildfires. By adding foam to water, all three sides of the fire triangle can be broken. Foam will cool, smother, and insulate the fuels. The aerated, water-containing bubble structure is effective only until the water has evaporated, and is, therefore, useful in direct attack, but not indirect attack.

(iii) *Retardants* are substances that reduce or inhibit the flammability of combustibles by chemical or physical action even after the water they originally contained has evaporated. The rate of spread of the flame is thereby slowed or retarded. Retardants are effective line-building tools for indirect attack, when applied following the 10 Principles of Retardant Applications (4, 5).

Fire line construction

A fire line is constructed for two purposes: to create a safe strip from which to start burning out to remove fuels between the fire line and advancing fire; and to isolate the burned area from the unburned area. The objective is to create a gap in the flammable materials. Fire line can be constructed using hand tools or mechanized equipment. The width of the fire line is dictated by the fuel, topography and fire behaviour. As a general rule, the fire line width should be at least 1½ times the height of the predominant fuel type. Table 2 provides general guidelines for the width of a fire line.

Use of fire

The use of fire to fight fire is very common in wildland firefighting. There are two types of uses: burning-out and backfiring. Burning-out involves the use of fire to remove the unburned fuels between the fire's edge and the control line. The fire can be used to great advantage in cleaning up and straightening line and widening natural or existing barriers. Backfiring is a special technique which requires extensive planning. Backfiring is used to control or turn a high-intensity fire front that will overrun fire lines if it cannot be slowed or stopped. The key to a successful backfire is that the main fire draws the backfire to it.

PROTECTIVE DEVICES

To lessen the health effects of air pollution caused by wildland fires, we must first understand the emissions resulting from these fires. The mixture of particles, liquids, and gaseous compounds found in smoke from wildland fire is very complex. The potential for long-term adverse health effects is much greater because of this complex mixture. The particles are known to contain many important organic compounds, some of which condense to form tarry droplets over a substrate material of ash or graphic carbon or both. The size distribution of smoke particles is such that a large percentage are respirable. Gaseous compounds in the air adjacent to fires in association with the particles include carbon monoxide, methane, oxides of nitrogen and many organic compounds, some of which are carcinogens and many of which are irritants. Some semi-volatile compounds have a significant vapour pressure at ambient temperature and pressure which results in a gas phase emission and many of these compounds are important from a health standpoint, but have not been adequately quantified. With the additional data of today, we still do not know what the overall toxicity of smoke is from wildland fires or how this toxicity varies from fire to fire (6). There are few studies which evaluate adverse health effects resulting from exposure to wildland fire smoke. Although many studies have been conducted on smoke constituents, there remains significant uncertainty with regard to the actual effects of that combination of pollutants which characterize wildland fire emissions. However, certain generalisations regarding adverse health effects of smoke and an analysis of the toxicity of the individual chemical compounds found in wood smoke can be useful in evaluating public health risks.

Breysse (7) discusses health hazards associated with smoke. The following information is based on his article and is quoted from the Prescribed Fire Smoke Management Guide, (8).

"Inhalation of smoke from whatever source can cause acute or chronic damage to health. The acute, or immediate symptoms are caused by exposure to high concentrations of smoke over short periods. Manifestations range from irritation of the eyes and respiratory tract to impaired judgement, semiconsciousness, unconsciousness, and even death.

More insidious are repeated exposures to relatively low concentrations. These may result in respiratory allergies, bronchitis, emphysema, and cancer. Chronic health hazards are by far the most significant, because 15 or more years usually pass before the victim is disabled.

Hazards vary with the kind of smoke inhaled. Smoke is a complex mixture whose components depend in part on the type of fuel, its moisture content, additives in the fuel (for example, pesticides sprayed on trees or foliage), and of course, the temperature of combustion. Burning forest fuels discharge hundreds if not thousands of chemical compounds into the atmosphere - including carbon monoxide, total suspended particulates, hydrocarbons, nitrogen oxides, and water vapour. Also released by burning vegetation are complex organic materials which are absorbed in, or on, condensed smoke particles. Penetration of these particles into the lung increases the chemicals' toxicity. Researchers consider particles with diameters of less than 10 μm to be inhalable. Researchers also consider particles with diameters less than 2.5 μm in diameter to be respirable. Over 90 per cent of particulate emissions from forest fires are

10 μm or less in diameter. The difference between the mass of particles produced that are less than 2.5 μm in diameter to the total mass of particulate matter increases proportionally to fire intensity.

In addition, nitrogen oxides and hydrocarbons produced by the fire react together in the presence of sunlight to produce ozone and organic oxidants. Both of these are potent irritants."

A recent study by Sharkey (9) states that smoke from wildland fires contributes to short-term and intermediate health effects. The effects have been shown to be reversible in most cases. Long-term exposure has the potential to cause or exacerbate health problems such as coronary artery disease, chronic obstructive pulmonary disease, and cancer. Individuals with asthma, allergies, or the capacity to develop reactive airways are more likely to be susceptible to the effects of smoke.

The common recommendations made to the general public to lessen the health effects of air pollution are: (i) stay indoors as much as possible if your indoor environment is air conditioned, keep windows and doors closed; (ii) wear respiratory masks if appropriate; and (iii) seek medical advice when called for.

Respiratory masks

The Occupational Safety and Health Administration (OSHA) and the National Institute of Occupational Safety and Health (NIOSH) are updating the standards that regulate the use and certification of respirators. Under the new regulations (42CFR Part 84), NIOSH will certify three classes of filters (N, R, and P) with three levels of efficiency (95, 99, and 99.97 per cent) in each class. The efficiency indicates the degree to which the filter removes small (0.3 μm) particulates. N series (not resistant to oil) particulate respirators are for protection from particulates that are free of oil or other severely degrading aerosols. These respirators have no time limitations and are suitable for wildland fire smoke. It should be noted that removing carbon monoxide from the breathing air currently requires converting of CO to CO_2 in an exothermic reaction. The process adds additional breathing resistance, increased respiratory work with the respiratory stimulus of carbon dioxide, and increases heat stress with the breathing of hot air. No currently available device protects the individual from all the hazards in smoke. Home-made or other commonly available masks may provide some relief but will not provide very little in terms of health protection.

Classification and description of respirators by mode of operation

Atmosphere-supplying respirators

A respirable atmosphere independent of the ambient air is supplied to the wearer.

Self-contained breathing apparatus (SCBA)

A supply of air, oxygen, or oxygen-generating material is carried by the wearer. It is normally equipped with full face piece, but may be equipped with a quarter-mask face piece, half-mask face piece, helmet, hood, or mouthpiece and nose clamp.

(i) Closed-circuit SCBA

These devices work with oxygen only, and produce either negative pressure in respiratory-inlet covering during inhalation or positive pressure in respiratory inlet covering during both inhalation and exhalation.

(a) Compressed or liquid oxygen type

It is equipped with a face piece or mouthpiece and nose clamp High-pressure oxygen from a gas cylinder passes through a high-pressure reducing valve and, in some designs, through a low-pressure admission valve to a breathing bag or container. Liquid oxygen is converted to low-pressure gaseous oxygen and delivered to the breathing bag. The wearer inhales from the bag, through a corrugated tube connected to a mouthpiece or face piece and a one-way check valve. Exhaled air passes through another check valve and tube into a container of carbon-dioxide removing chemical and reenters the breathing bag. Make-up oxygen enters the bag continuously or as the bag deflates sufficiently to actuate an admission valve. A pressure-relief system is provided, and a manual by-pass system and saliva trap may be provided depending upon the design.

(b) Oxygen-generating type

It is equipped with a face piece or a mouthpiece and nose clamp. Water vapour in the exhaled breath reacts with a chemical in the canister to release oxygen to the breathing bag. The wearer inhales from the bag through a corrugated tube and one-way check valve at the face piece. Exhaled air passes through a second check valve/breathing tube assembly into the canister. The oxygen-release rate is governed by the volume of exhaled air. Carbon dioxide in the exhaled breath is removed by the canister fill.

(ii) Open-circuit SCBA

This devices works with compressed air, compressed oxygen, liquid air or liquid oxygen. A bypass system is provided in case of regulator failure except on escape-type units.

(a) Demand type

This type is equipped with a face piece or mouthpiece and nose clamp and with a demand valve that is activated on initiation of inhalation and permits the flow of breathing atmosphere to the face-piece. The demand valve permits oxygen or air flow only during inhalation. Exhaled breath passes to ambient atmosphere through a valve in the face piece. On exhalation, pressure in the face piece becomes positive and the demand valve is deactivated.

(b) Pressure-demand type

This type is equipped with a face piece only. Positive pressure is maintained in the face piece by a spring-loaded or balanced regulator and exhalation value. The apparatus may have provision for the wearer to select the demand or pressure-demand mode of operation; in which case, the demand mode should be used only when donning or removing the apparatus.

Supplied-air respirators

(i) Hose mask

This type is equipped with a face piece, a breathing tube, a rugged safety harness, and a large-diameter heavy-duty non-kinking air-supply hose. The breathing tube and air-supply hose are securely attached to the harness. The face piece is equipped with an exhalation valve. The harness has provision for attaching a safety line.

(a) Hose mask with blower

Air is supplied by a motor-driven or hand-operated blower. The wearer can continue to inhale through the hose if the blower fails. Up to 91 metres of hose length is permissible.

(b) Hose mask without blower

The wearer provides motivating force to pull air through the hose. The hose inlet is anchored and fitted with a funnel or like object covered with a fine mesh screen to prevent entrance of coarse particulate matter. Up to 23 metres of hose length is permissible.

(ii) Air-line respirator

Respirable air is supplied through a small-diameter hose from a compressor or compressed-air cylinders. The hose is attached to the wearer by a belt or other suitable means and can be detached rapidly in an emergency. A flow-control valve or orifice is provided to govern the rate of air flow to the wearer. Exhaled air passes to the ambient atmosphere through a valve(s) or opening(s) in the enclosure (face piece, helmet, hood, or suit). Up to 91 meters of hose length is permissible.

There are three types of air-line respirators: continuous-flow class, demand type and pressure-demand type.

(a) Continuous-flow class

It is equipped with a face piece, hood, helmet, or suit. At least 115 liters of air per minute to tight-fitting face pieces and 170 liters of air per minute to loose-fitting helmets, hoods, and suits is required. Air is supplied to a suit through a system of internal tubes to the head, trunk, and extremities through valves located in appropriate parts of the suit.

(b) Demand type

This type is equipped with a face piece only. The demand valve permits flow of air only during inhalation.

(c) Pressure-demand type

This type is equipped with a face piece only. A positive pressure is maintained in the face piece.

(iii) Combination air-line respirators with auxiliary self-contained air supply

These respirators include an air-line respirator with an auxiliary self-contained air-supply. To escape from a hazardous atmosphere in the event the primary supply fails to operate, the wearer switches to the auxiliary self-contained air supply. Devices approved for both entry into and escape from dangerous atmospheres have a low-pressure warning alarm and contain at least 15-minutes self-contained air supply.

Air-purifying respirators

Ambient air, prior to being inhaled, is passed through a filter, cartridge, or canister which removes particles, vapours, gases, or a combination of these contaminants. The breathing action of the wearer operates the nonpowered type of respirator. The powered type contains a blower - stationary or carried by the wearer - which passes ambient air through an air-purifying component and then supplies purified air to the respirator-inlet covering. The nonpowered type is equipped with a face piece or mouthpiece and nose clamp. The powered type is equipped with a face piece, helmet, hood, or suit.

(i) Vapour- and gas-removing respirators

It is equipped with cartridge(s) or canister(s) to remove a single vapour or gas (for example: chlorine gas), a single class of vapours or gases (for example: organic vapours), or a combination of two or more classes of vapours or gases (for example: organic vapours and acidic gases) from the air.

(ii) Particulate-removing respirators

It is equipped with filter(s) to remove a single type of particulate matter (for example: dust) or a combination of two or more types of particulate matter (for example: dust and fume) from the air. The filter may be a replaceable part or a permanent part of the respirator. The filter may be of the single-use or the reusable type.

(ii) Combination particulate- and vapour- and gas-removing respirators

It is equipped with cartridge(s) or canister(s) to remove particulate matter, vapours, and gases from the air. The filter may be a permanent part or a replaceable part of a cartridge or canister.

(iii) Combination atmosphere-supplying and air-purifying respirators

They provide the wearer with the option of using either of the two different modes of operation: (i) an atmosphere-supplying respirator with an auxiliary air-purifying attachment which provides protection in the event the air supply fails; or (ii) an air-purifying respirator with an auxiliary self-contained air supply which is used when the atmosphere may exceed safe conditions for use of an air-purifying respirator.

Respiratory protective equipment

The basic purpose of any respirator is to protect the respiratory system from inhalation of hazardous atmospheres. Respirators provide protection either by removing contaminants from the air before it is inhaled or by supplying an independent source of respirable air.

Air-purifying respirators

Ambient air, prior to being inhaled, is passed through a filter, cartridge, or canister which removes contaminants. Different filters are required to remove different contaminants.

(i) Nonpowered air-purifying respirator

The breathing action of the wearer operates the nonpowered type of respirator. Equipped with a tight-fitting face piece and filter(s), the respirator is secured to the face by means of a strap or harness. The wearer draws air through the filters during inhalation.

The dust mask is a single-use respirator generally approved only for nuisance dusts such as cement and hay dusts. These respirators should be discarded when resistance to breathing becomes excessive.

The half-mask and full face piece respirators provide greater protection than the dust mask because their design allows for a better fit. These respirators provide protection against dusts, mists, fumes, vapours, gases, or any combination of these contaminants depending on the type of filter used. The full face piece respirator provides the greatest degree of protection and protects the eyes as well.

Many different filter elements are available. Vapour cartridges should be changed when odours "breakthrough", and are noticeable inside the mask. Some chemicals, such as mercury, have no odour and require a special filter that has an end-of-service-life indicator. It is important to choose the right filter or combination of filters for a given job.

(ii) Powered air-purifying respirator (PAPR)

The powered type contains a portable blower which pushes ambient air through a filter and then supplies purified air to the wearer. The powered type is equipped with a tight-fitting face piece or a loose-fitting helmet, hood, or suit. The figure shows a tight-fitting face piece which provides a higher degree of protection than a loose fitting hood or helmet.

Atmosphere-supplying respirators

A respirable atmosphere, independent of the surrounding air, is supplied to the wearer. Atmosphere-supplying respirators provide a greater level of protection than air-purifying respirators because they do not rely on a filtering mechanism to provide clean air.

(i) Self-contained breathing apparatus (SCBA)

A supply of air, oxygen, or oxygen-generating material is carried by the wearer. The device is normally equipped with a full face piece, but may be equipped with a half-mask face piece, helmet, hood, or mouthpiece and nose clamp.

(ii) Air-line respirator

Respirable air is supplied through a small-diameter hose from a compressor or compressed air cylinder. The hose is attached to the wearer by a belt and can be detached rapidly in an emergency. A flow-control valve or orifice is provided to govern the rate of air flow to the wearer. Exhaled air passes to the ambient atmosphere through a valve or opening in the enclosure (face piece, helmet, hood, or suit).

(iii) Breathing air quality

Compressed air, compressed oxygen, liquid air, and liquid oxygen used for respiration shall be of high purity. Oxygen shall meet the requirements of the United States Pharmacopoeia for medical or breathing oxygen. Breathing air shall meet at least the requirements of the specification for Grade D breathing air (10). A compressor used to supply breathing air shall be a breathing air-type compressor. Compressors shall be constructed and situated so as to avoid entry of contaminated air into the system and suitable in-line air-purifying sorbent beds and filters installed to further assure breathing air quality.

Respirator programme equipment

Respirator selection

Respirators will be selected by a qualified safety and health professional. The following factors shall be taken into account when selecting the proper respirator:

Characteristics of hazardous operation or process

- Hot operations: welding, chemical reactions, soldering, melting, moulding and burning
- Liquid operations: painting, degreasing, dipping, spraying, brushing, coating, etching, cleaning, pickling, plating, mixing, galvanizing and chemical reactions
- Solid operations: pouring, mixing, separations, extraction, crushing, conveying, loading, bagging and demolition.
- Pressurized spraying: cleaning parts, applying pesticides, degreasing, sand blasting and painting
- Shaping operations: cutting, grinding, filing, milling, moulding, sawing and drilling

Nature of hazard

(a) Gaseous contaminants

- Inert gases (helium, argon, etc.), which do not metabolize in the body but displace air to produce an oxygen deficiency.
- Acid gases (SO_2, H_2S, HCl, etc.) which are acids or produce acids by reaction with water.
- Alkaline gases (NH_3, etc.), which are alkalies or produce alkalies by reaction with water.

- Organic gases (butane, acetone, etc.), which exist as true gases or vapours from organic liquids.

- Organometallic gases (tetraethyl lead, organophosphates, etc.), which have metals attached to organic groups.

(b) *Particulate contaminants*

- Dusts which are mechanically generated solid particulates (0.5 to 10 μm)

- Fumes which are solid condensation particles of small diameter (0. 1 to 1.0 μm)

- Mists which are liquid particulate matter (5 to 100 μm)

- Smoke which is chemically generated particulates (solid and liquid) of organic origins (0.01 to 0.3 μm)

Concentration of contaminant

(a) *Immediately dangerous to life and health (IDLH)*

These are conditions that pose an immediate threat to life or health or conditions that pose an immediate threat of severe exposure to contaminants, such as radioactive materials. Air-purifying respirators are never to be used in IDLH atmospheres.

(b) *Short term exposure limit (STEL)*

This refers to an exposure limit that is the maximum concentration to which workers can be exposed for a period of up to 15 minutes with no detrimental effects.

(c) *Threshold limit value (TLV)*

These are the upper exposure limits of airborne concentrations that are accepted as safe for employees to be exposed to on a day-in, day-out basis. The time weighted average (TWA) is the maximum concentration that employees working eight hours per day, forty hours per week can be exposed to with no adverse health effects.

Respirator design

(a) NIOSH/MSHA-approved respirators

All respirators used on campus must be approved by the National Institute of Occupational Safety and Health (NIOSH) or the Mine Safety and Health Administration (MSHA). NIOSH-approved respirators are labelled with a NIOSH ID number. Filters are labelled with the type of hazard the respirator is approved to protect against. Respirator replacement parts are labelled with part numbers and only approved replacement parts should be used. Any modifications that do not use approved replacement parts void the approval of the respirator.

(b) Enclosure design (Figure 4)

- Tight-fitting units: full face piece and half-mask
- Loose-fitting units: hood, helmet, and enclosed suit

Worker activity

- Duration of job
- Physical exertion: light, medium, heavy
- Temperature of job area

Training

Each wearer shall be given initial training by the ORCBS covering the following topics:

- respiratory hazards and health effects;
- how respirators work;
- engineering controls vs respirator use;
- medical evaluation;
- respirator selection rationale;
- fit testing;

- respirator donning & fit checks; and
- maintenance, cleaning and storage.

MITIGATION MEASURES

The knowledge of how wildland fire burns, occupancy, cultural use of fire, emission factors and rates, and dispersion are all critical in developing mitigation strategies. The following mitigation measures will focus on (i) emissions factors and rates; (ii) control strategies for agricultural burning; (iii) smoke monitoring and evaluation; and (iv) wildfire smoke emergency action plan guidance. Because most of the adverse impacts from wildland fire are caused by particulate matter in the smoke under adverse meteorological conditions, we must be able to estimate the amount of smoke that will be produced. The answer can be derived via two numerical terms, emission factor and emission rate (11).

Emission factors and rates

An emission factor for particulate matter (EFp) is defined as the mass of particulate matter produced per unit mass of fuel consumed; ie. g/kg. Emission factors reported in the literature for forest fuels range from four to 19 g/kg, depending on fuel type and arrangement and the manner of combustion. In general, fuels consumed by flaming combustion produce much less particulate matter than fuels consumed by smouldering combustion. Suggested EFp values for generalized fuels are listed in Table 3. These values can be used as a guide to develop regional expressions of the most common fuel and fire types. They can also be used by local air quality agencies that need emission inventory information. The emission factors are generalised estimates based on research data, combustion fundamentals and scientific judgement. They should be modified as needed in regional supplements to this guide in accordance with the latest information on fuels, firing technique, smoke particle size, etc.

Emission rate is defined as the amount of smoke produced per unit of time (g/min). Down wind concentrations of particulate matter in smoke are related directly to the emission rate at the fire source; the emission rate, in turn, is affected by the amount of fuel being burned, the rate at which it burns, and the emission factor of the fuel.

The amount of fuel actually consumed by a fire is called available fuel, and this fuel may be consumed by flaming or smouldering combustion. The unit of measure is usually in kg/ha. The land manager can make better estimates of emission rates from a fire if the amount of fuel consumption in each of the two types of combustion is known. Available fuel can be estimated before ignition and is usually less than the total fuel loading. The rate at which fuel is consumed can be expressed as the area burned per unit of time (ha/min). The combustion rate can be calculated for backing or head fires in natural or in activity fuels.

Once estimates of the available fuel, the combustion rate, and the emission factor (g/kg) are made, the emission rate can be calculated by the equation:

Emission Rate (g/min) = available fuel (kg/ha) x combustion rate (ha/min) x emission factor (g/kg)

The emission rate is used to drive models that predict concentrations of particulate matter. These models are used to assess the impact of smoke on visibility in sensitive areas such as cities, highways, and airports.

Control strategies for agricultural burning

Avoidance, dilution, and emission reduction are ways to manage smoke from wildland fires. Avoidance is a strategy of considering meteorological conditions when scheduling fires in order to avoid incursions into smoke sensitive areas; for example, a populated area where any noticeable impact is objectionable. Dilution involves controlling the rate of emissions or scheduling for dispersion to assure a tolerable concentration of smoke in designated areas. Emission-reduction techniques minimize the smoke output and decrease the contribution to regional haze as well as intrusions into designated areas. One way to reduce emissions is to treat fuels and prepare seedbeds using treatments other than fire, including the option of no treatment.