TECHNICAL SPECIFICATION

ISO/TS 19677

First edition
2019-02

Guidelines for assessing the adverse impact of wildland fires on the environment and to people through environmental exposure

Lignes directrices pour l'évaluation de l'impact négatif des feux d'espaces naturels sur l'environnement et les personnes par exposition environnementale

Reference number
ISO/TS 19677:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 3, *Fire threat to people and environment*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document gives guidance and provides a methodology for assessing the adverse environmental impact of wildland fires and wildland firefighting operations. The serious consequences of the adverse impact of fire effluent from forest, shrubland and grassland fires to the environment and to people, through environmental exposure, have confirmed that it is an important issue that urgently needs to be dealt with internationally and systematically. This document provides a framework for a common treatment of the environmental impact of wildland fires.

General awareness of the fact that large wildland fires present serious and persistent adverse effects on the environment has been accentuated by a number of high impact incidents over the past half century. In Annex A, some recent wildland fire incidents are listed and their environmental impact is described.

This document has been prepared in accordance with ISO Guide 64[1].

Guidelines for assessing the adverse impact of wildland fires on the environment and to people through environmental exposure

1 Scope

This document addresses the impact of wildland fires and firefighting activities on the environment (air, water, soil, wildlife and vegetation). It further addresses the impact of wildland fire effluents on exposed human population, including firefighters, as well as food production, land, sea and air traffic, and the built environment. It also describes the environmental impacts of firefighting activities.

This document also provides requirements and recommendations to quantify such impacts of wildland fires and to establish post-fire mitigation measures.

The wildland fires covered include both natural wildland fires and man-initiated fires, including prescribed burning and agricultural fires, but not peat fires nor coal seam fires.

This document is intended to serve as a tool for the development of standard protocols for:

— the assessment of local and remote adverse environmental impacts of wildland fires;

— the assessment of the effects of smoke and gas exposure on firefighters and exposed human populations.

It provides guidance for incident commanders and other responsible or affected parties when decisions regarding firefighting strategies, tactics, and restoration are made. It is intended principally for use by firefighters and investigators, insurance providers, environmental regulatory authorities, civil defence organisations, public health authorities and land owners.

This document does not include specific instruction on compiling and reporting the information needed to assess environmental damage caused by a fire incident, nor does it include specific sampling methodologies and analysis requirements. These topics are the focus of documents in the ISO 26367 series. This document does not address either fire damage to the built environment, direct acute toxicity issues, which are covered by other ISO standards, nor does it address economic impact, although the impact of climate change is discussed in Annex D.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13943, *Fire safety — Vocabulary*

ISO 14050, *Environmental management — Vocabulary*

ISO 26367-1, *Guidelines for assessing the adverse environmental impact of fire effluents — Part 1: General*

ISO 26367-2, *Guidelines for assessing the adverse environmental impact of fire effluents — Part 2: Methodology for compiling data on environmentally significant emissions from fires*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943, ISO 14050, ISO 26367-1 and ISO 26367-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
fuel
<wildland fires> biomass of a defined maximum cross-section

Note 1 to entry: It is expressed in tonnes per hectare ($t.ha^{-1}$).

[SOURCE: AFAC Bushfire Glossary[2]]

3.2
wildland
land that either has never suffered human intervention or has been allowed to return to its natural state, or that is managed for forestry or ecological purposes

3.3
wildland fire
fire occurring in forests, scrublands, grasslands or rangelands, either of natural origin or caused by human intervention[SOURCE: NFPA 1144[3]]

3.4
wildland urban interface
WUI
area where structures and other human development adjoin or overlap with wildland

[SOURCE: AFAC Bushfire Glossary]

4 Wildland fire variables

The following variables shall be considered when evaluating the environmental impact of wildland fires. They all have an impact on combustion efficiency and environmental impact[4]. Depending on the particular fire conditions, there can be other variables that are also important to consider.

— Fire size: influences the quantities of airborne pollutants that are produced.

— Fire duration: influences the quantities of airborne pollutants that are produced and the impact they have on soils.

— Fuels: fuel type and form, moisture content and fuel density affect the fire intensity and rate of spread. In a particular wildland fire, either the predominant fuel is grass, scrub or trees, or the fire can progress from an area with one predominant form of fuel to an area with a different predominant form of fuel.

— Topography: upslope conditions result in a fire that produces different emissions from those produced by a fire occurring under no slope or downslope conditions; the former case results in more efficient combustion. Slopes are also more prone to erosion following a fire[5]. Post-fire turbidity levels in watercourses are affected by the steepness of the burned slopes[6].

— Weather preceding a fire: includes precipitation (rain, snow, sleet, hail), air temperature and humidity. For example, high temperatures, no rainfall and low humidity result in a fire that produces different emissions from those produced by a fire occurring after a period of low temperatures, rainfall and high humidity; the former case results in more efficient combustion[7]. Prolonged drying is not necessary. Surface fuels can dry out sufficiently to support a fire in one week without rain[8].

— Weather during a fire: includes wind speed, air temperature and humidity. For example, high winds, high temperatures and low humidity result in a fire that produces different emissions from those produced by a fire occurring when there is little or no wind, low temperatures and high humidity; the former case results in more efficient combustion.

— Weather following a fire: includes precipitation (rain, snow, sleet, hail), and humidity. Rainfall immediately after a fire can lead to soil loss and contamination of water supplies. Humidity has an influence on the nature and persistence of aerosols and particulates in smoke plumes.

5 Environmental impact of wildland fires

5.1 General

This Clause describes the nature of environmental impacts of wildland fires on the following:

— air (see 5.2),

— water (see 5.3),

— soil (see 5.4),

— wildlife (see 5.5),

— vegetation (see 5.6),

— exposed human populations (see 5.7), including firefighters (see 5.8),

— food production (see 5.9),

— land, sea and air traffic (see 5.10), and

— the built environment (see 5.11).

The effect of recurrence is considered. Individual fires have some effects, but recurrent fires are particularly responsible for adverse impact on vegetation and soil[9].

Firefighting activities can also have a significant environmental impact[10]. This is presented in Clause 6.

For each case, quantification techniques and post-fire mitigation measures are specified. Post-fire mitigation includes both short-term and long-term measures.

Overall, factors that shall be considered in assessing the total impact of wildland fires include ecological, social and health-related.

NOTE The economic impact is not addressed in this document but a methodology for assessing socio-economic impact of wildland fires is available[11].

5.2 Fire testing and data collection

As relevant quantitative data on environmentally hazardous components of fire effluent cannot routinely be obtained from actual wildland fires, appropriate data have also to be obtained from prescribed burns, real-scale fire tests and simulations involving physical fire models.

Real-scale wildland fire tests have many limitations. As well as problems regarding repeatability due to variations in weather conditions, slope and vegetation heterogeneity, real-scale fires are often conducted out of the fire season when conditions are vastly different to those occurring during actual fires.

Although real-scale fire tests provide important information concerning the fire dynamics, some measurements can be conducted at laboratory scale. Both real-scale fire tests and laboratory experiments are complementary and necessary.

While real-scale fire tests provide important information concerning airborne emissions, some measurements, such as emission factors (for carbon monoxide (CO) and carbon dioxide (CO_2) for instance), can be conducted at laboratory scale[12]; however, caution is necessary. Laboratory data can overestimate the quantity of emissions of some species[13].

5.3 Impact of wildland fire on air

5.3.1 Nature of impact

Airborne emissions from wildland fires comprise particulates, aerosols and gases. Wildland fires are a significant source of airborne particulate matter on a global scale[14]. Concerns include acute health effects near the fires[4], climate effects and regional visibility[15]. Human health effects are addressed in 5.8.

The production of aerosols plays an important role in the regional radiative balance and can produce regional cooling[16]. Forest fires, when compared to all fires, are a significant source of polyaromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs)[17].

Prescribed burns can also have a significant impact on air quality, due to the production of airborne particulates, such as fine particles ($PM_{2.5}$)[18]. Prescribed burning can produce smaller smoke plumes than wildland fires[19].

Agricultural fires can cause long-term air quality issues[20].

As well as the primary combustion products, secondary combustion products can result from photochemical reactions in the smoke plume[21].

A list of major airborne combustion products is given in Annex B.

5.3.2 Quantification of impact

An estimate of the total quantities of pollutants produced in a wildland fire shall be modelled. The USDA First Order Fire Effects Model (FOFEM)[22], or a similar model, can be used.

During prescribed burns, land-based measuring stations should be used to record both gases and particulates[23].

Aircraft should be used to carry out comprehensive analyses of smoke plumes[25].

In areas remote from a wildland fire, the impact on air quality should be measured by a three-hour Pollutant Standards Index (PSI), such as the one developed by the U.S. Environmental Protection Agency[25], or similar model.

NOTE In the PSI system, a measure of air-quality readings within the 51 to 100 range indicate “moderate” air quality, while the range of 101 to 200 points to “unhealthy” conditions. Measurements between 201 and 300 represent “very unhealthy” conditions, while readings above 300 indicate a “hazardous” situation.

5.3.3 Mitigation of impact

It is difficult to control the impact of wildland fires of uncontrolled origin. The wildland fire variables described in Clause 4 are important factors. However, where wildland fires are the result of agricultural practices or prescribed burning, attention shall be paid to weather and climate factors. In particular, wind conditions shall be considered.

5.4 Impact of wildland fire on water

5.4.1 Nature of impact

Water bodies that can be affected include streams, rivers, lakes, water storages, aquifers and coastal waters. Contaminants can come from water run-off from firefighting activities or rain following fires.

Contamination can be caused by combustion products of vegetation, combustion products of manufactured items or structures, soils loosened by vegetation loss, and firefighting activities. Contamination resulting from firefighting activities is addressed in Clause 6.

Pollutants can be solid or liquid. Solids can be soluble or insoluble in water. Soluble materials can be toxic to riverine wildlife; insoluble materials can cause discolouration and cloudiness which can interfere with the ecology of a waterway[26].

Run-off can be contaminated by combustion products of manufactured products. Examples include preservatives used in timber construction, such as copper chrome arsenate (CCA).

Vegetation removal can lead to erosion and soil loss by wind and by rain for an extended period after the fire. If these sediments run-off into a nearby watercourse, pollution can result. Water temperatures in watercourses can increase due to both radiation and run-off[6].

Run-off from fires in coastal areas can have a negative impact on the ecology and biota of coastal regions and coral reefs.

5.4.2 Quantification of impact

Existing water monitoring stations shall be used to provide data on the impact of wildland fires on water quality[27].

5.4.3 Mitigation of impact

Guidelines for mitigating the impact of activities resulting from wildland fires shall be provided. Measures recommended include wedging straw or hay bales across run-off routes[28].

In some cases, such as in 5.4.3.1 and 5.4.3.2, special guidelines shall be implemented.

5.4.3.1 Firefighting chemicals and firefighting water

Both land and aerial application shall be considered.

For land application, the following guidelines, based on USDA guidelines[29], shall be implemented to minimize the likelihood of firefighting chemicals entering a stream or other body of water.

— During training or briefings, inform field personnel of the potential danger of fire chemicals, especially foam concentrates, in streams or lakes.

— Locate mixing and loading points where contamination of natural water, especially with foam concentrate, is minimal.

— Maintain all equipment and use check valves where appropriate to prevent release of foam concentrate into any body of water.

— Exercise particular caution when using any fire chemical in watersheds where water abstraction, fisheries, fish hatcheries or other sensitive habitats are located.

— Locate dip operations to avoid run-off of contaminated water back into the stream.

— Dip from a tank rather than directly from a body of water, to avoid releasing any foam into these especially sensitive areas.

— Use a pump system equipped with check valves to prevent flow of any contaminated water back into the source body of water.

— Avoid direct drops of retardant or foam into rivers, streams, lakes, or along shores. Use alternative methods of fire line building in sensitive areas.

— Notify proper authorities promptly if any fire chemical is used in an area where there is likelihood of negative impacts.

The aerial application of retardant or foam within 100 m of waterways shall be avoided[30]. Where such an application occurs, the adverse effects on threatened and endangered species shall be assessed immediately[31].

5.4.3.2 Post-fire salvage harvesting operations

The following guidelines, as recommended by the Australian CRC for Forestry[32] to mitigate impacts on run-off, erosion and water quality, shall be implemented:

— Remove logs up-slope when cable harvesting if permitted by the road network.

— Do not disturb riparian buffers.

— Place logs and harvest slash in the run-off convergence zones (areas where run-off accumulates from multiple up-slope directions) of harvested sub-catchments.

— Retain and distribute harvest slash across hill slopes.

— Apply additional erosion control measures (e.g. mulch) to harvested hill slopes.

5.5 Impact of wildland fire on soil

5.5.1 Nature of impact

Adverse impacts include breakdown of surface structure, deposition of ash and impact on soil microbial communities[33]. There are also non-adverse effects such as recycling of nutrients[34]. Nutrient losses can be enhanced by soil leaching and erosion[35]. A major short-term impact is an increase in pH[35].

Pollutants can be solid or liquid. Solids can be soluble or insoluble in water.

The application of firefighting chemicals can impact on soil microbial communities[36].

Vegetation removal can lead to erosion and soil loss by wind and by rain.

5.5.2 Quantification of impact

Spatial analysis modelling shall be used to maximise the benefits of erosion control activities[5].

Soils shall be sampled prior to and following prescribed burning in order to study changes in soil nutrients[34].

5.5.3 Mitigation of impact

Guidelines on reducing soil erosion shall be provided.

NOTE Techniques for the prevention of erosion and soil loss are dependent on the local ecology and climate.

In the short term mulching and planting of seeds shall be used to encourage the regrowth of grasses[35]. Long term mitigation should include reforestation where appropriate.

5.6 Impact of wildland fire on vegetation

5.6.1 Nature of impact

Remnant populations of endangered species of vegetation can be extremely vulnerable to wildland fires.

Plant communities can be very complex, and the loss, temporary or permanent, of one species can have an impact on other species.

Some species respond more rapidly than others after a fire. Fire can lead to a change in the dominant species in an area[37].

Long-term firefighting chemicals can act as nutrients, having both positive and negative impacts on vegetation[26]. The presence of firefighting chemicals can produce greater increases in soil pH than that produced by the fire itself[36].

Short-term firefighting chemicals (foams) can have an impact on the health of plants[26]. They can increase the effects of fire on cations in the soil[36]. Some details are given in Annex C.

5.6.2 Quantification of impact

Studies shall be undertaken on the quantification of the impact of wildland fires on vegetation.

NOTE An example is the study undertaken by the United States Department of Agriculture Forest Service[38].

5.6.3 Mitigation of impact

Steps to be undertaken shall include protecting vegetation from further damage caused by run-off; re-seeding as rapidly as possible, and restricting access to critical areas.

5.7 Impact of wildland fire on wildlife

5.7.1 Nature of impact

Remnant populations of endangered species can be extremely vulnerable to wildland fires.

Amphibian diversity can be affected with increased frequency of prescribed burns[39].

Habitat loss can lead to non-viable populations of species.

Fire retardant chemicals can be toxic to aquatic wildlife and mammals[32].

5.7.2 Quantification of impact

Studies shall be carried out on the most endangered species; in particular the amount of habitat destruction shall be quantified.

NOTE An example of such a study is the quantification of habitat loss for a possum species after the fires in Central Victoria in 2009[40].

5.7.3 Mitigation of impact

Only firefighting chemicals that have been tested and meet specific requirements with regard to mammalian toxicity shall be used[29].

5.8 Impact of wildland fire on exposed human populations

5.8.1 Nature of impact

The predominant impact is from airborne combustion products. Some combustion products of major concern are listed in Annex B.

The main pollutants are persistent gases and fine particulate matter. Pesticides and combustion products of pesticides can be released[41].

While most emissions are from the biomass consumed in the fire, the emissions from man-made articles, including buildings, building contents and structures cannot be ignored[42].

As well as the short-term effects of smoke and gas exposure, prolonged exposure can lead to long-term effects.

Smoke haze from forest fires can have deleterious effects on the health of distant human populations[43]. Smoke haze from wildland fires can significantly increase the mortality burden for affected human populations, and has large effects for vulnerable groups, such as seniors[44].

Forest workers are a special category of exposed human populations, being more likely to face exposure to combustion products of pesticides[41].

If the fire spreads to buildings or infrastructure, either in farmland or at the wildland urban interface (WUI), hazardous household materials can be present after the fire, including asbestos, ash from burnt treated timbers (including CCA), medicines, and garden or farm chemicals[45].

The following respiratory health impacts have been identified:

— people with chronic respiratory illness can experience a worsening in their respiratory symptoms.

— There can be an increased incidence of mild respiratory symptoms amongst previously healthy individuals, which can require some medical treatment.

— Increased doses of anti-inflammatory and bronchodilator medication can be required.

Whilst airborne combustion products provide the major impact on health, exposures to contaminated soil and water are also health threats[46].

5.8.2 Quantification of impact

When estimating exposures to combustion products, risk assessment methods shall be used[21].

5.8.3 Minimising health threats to exposed human populations

Human populations exposed to wildland fire emissions shall be warned of the dangers of exposure to smoke through education and information brochures[47]. Where possible, human populations at risk shall be monitored for effects of exposure to irritants and toxicants that can lead to respiratory or other health problems.

In areas frequently exposed to airborne pollutants from wildland fires, the provision of public notifications of pollutant types and concentrations shall be considered.

If necessary, human populations shall be advised to stay indoors and drink more water[25]. Closure of schools can be necessary[48].

Human populations shall be advised of post-fire hazards that can exist, especially in WUI zones[49].

Guidelines for mitigating the environmental impact on health shall be followed, such as the following extracted from the PLOS Currents: Disasters[46], or similar:

Minimising exposure to smoke

— Air quality reports should be checked. These can have the potential to be used in conjunction with syndromic surveillance to understand health effects and their link with air pollution.

— Indoor air should be kept as unpolluted as possible by keeping windows and doors closed and shutting off external ventilation.

Access and egress

— Systems should be in place to ensure delivery of medication and provisions to those who need them, especially vulnerable groups.

— People living in areas prone to wildland fires can be advised to keep a stock of 5 days of non-perishable provisions and medications.

Visibility

— Road users should be made aware of the potential for low visibility when driving.

— Anyone presenting with eye irritation should be screened for corneal abrasion.

Communication

— Public health information should be clear and as accurate as possible.

— People with pre-existing health conditions should be made aware of the potential adverse health impact of wildland fire smoke. For example, asthma sufferers should be advised to increase their medication if they are likely to be exposed to smoke.

5.9 Impact of wildland fire on firefighters

5.9.1 Nature of impact

The predominant impact is from airborne combustion products. Some combustion products of major concern are listed in Annex B.

The main pollutants are persistent gases and fine particulate matter. Pesticides and combustion products of pesticides can be released[41].

Firefighters are likely to have a more severe exposure than exposed human populations but are also more likely to have breathing protection.

Short-term smoke and gas exposures that impact on firefighters include CO, high temperature air, $PM_{2.5}$[23] and other respirable particles; aldehydes; and VOCs. The exposure is dependent both on task being performed and nature of fuel[50].

Short term adverse health effects include coughing, eye irritation, shortness of breath, headaches, dizziness and nausea. Long-term health effects can include impaired respiratory function or increased risk of cancer.

5.9.2 Quantification of impact

Where possible, firefighters shall be fitted with personal automatic gas and particulate sampling devices which allow monitoring of the environments to which firefighters are exposed. This is easier to achieve during prescribed burns.

Risk assessment methods shall be used to estimate firefighter exposures to combustion products[21].

5.9.3 Mitigation of impact

Suitable breathing apparatus shall be supplied to firefighters. Firefighters exposed to wildland fire emissions shall be assessed according to workplace occupational health and safety (OHS) requirements.

5.10 Impact of wildland fire on food production

5.10.1 Nature of impact

Some firefighting chemicals contain additives that, on breaking down, are toxic to fish[10]. The degree of toxicity varies with the fire retardant and the species of fish[26].

Wine regions can suffer a decline in product quality following either wildland fires or prescribed burns[51].

5.10.2 Quantification of impact

The nature of the impact shall be defined. Both the range of food sources and the size of the loss of each shall be considered.

5.10.3 Mitigation of impact

Post-fire mitigation measures appropriate to the type of food source under threat shall be implemented.

5.11 Impact of wildland fire on land, sea and air traffic

5.11.1 Nature of impact

Driving through smoke is a recognised hazard[52]. Low visibility can result in death and injury through collisions.

The most common impact of wildland fires on air traffic is reduced visibility, though fire-induced winds can also impact on aircraft movement[8]. Wildland fires can cause low visibility at airports, increasing the dangers of landing[53]. Airports may have to be closed[8].

Large wildland fires can produce convective columns over 10 000 m high. These convective columns can contain both updrafts and downdrafts which can produce extreme turbulence and wind shear. Wind shear is a particular hazard for low-flying aircraft[8].

5.11.2 Quantification of impact

Sonic anemometers shall be used to assess the wind flow in the vicinity of fire[54].

Because of the temperature level near the fires, such sensors cannot be used very close to the fire. Nevertheless, the assessment of wind flow in wildland fires is possible by using remote sensors like Doppler lidar as shown during a low-intensity prescribed fire[55]. However, such ground-based scanning Doppler lidar acquired only the radial wind velocities. Moreover, the convective column shall not be too optically dense in order to allow the lidar penetration inside the plume.

Plumes should be tracked by satellite or aircraft to obtain data for quantifying their overall impact[56].

5.11.3 Mitigation of impact

In areas where highways are prone to regular smoke-logging, permanent highway warning signs shall be provided[57].

Warnings on reduced visibility shall be provided to land traffic by commercial radio and to air and sea traffic controllers. Where necessary, road detours shall be provided, shipping lanes diverted and airports closed.

5.12 Impact of wildland fire on the built environment

5.12.1 Nature of impact

Buildings and other structures can suffer environmental impact from wildland fires. Environmental effects can include indoor air pollution, damage from firefighting activities, damage from water run-off and corrosion. Direct fire damage is not within the scope of this document.

5.12.2 Quantification of impact

Affected elements of the built environment need to be inspected to determine the nature and severity of environmental impacts.

5.12.3 Mitigation of impact

Early warning of potential environmental impact shall be provided wherever possible. Advice on likely fire plume severity, direction and height shall be promulgated, as well as information on weather. Critical infrastructure, such as communications facilities, shall be protected as much as possible from corrosion resulting from rainfall interacting with the fire plume.

6 The impact of firefighting activities

6.1 Nature of impact

The ecological effects of wildland firefighting activities can be significant and can exceed the effects of the fire itself. These effects can result from construction of fire lines, air pollution from firefighting vehicles, and backburning[10].

Soil compaction can occur from the construction of fire camps, fire lines, helipads, incident command posts and roads. Erosion can result from the construction of fire lines and roads. Air pollution can result from the burning of liquid fuels by aircraft and machinery. Sedimentation can result from construction of log erosion barriers, fire camps, fire lines and roads. Pollution can occur from fire camps and liquid fuel spillage.

Many firefighting chemicals are nutrients, and pollution of waterways by firefighting chemicals can lead to the formation of algal blooms, eutrophication[58] or other undesirable effects. A list of common firefighting chemicals and their environmental impacts is given in Annex C.

Many firefighting chemicals have been found to be toxic to fish, aquatic invertebrates and algae[26].

Nutrients and sediments can be washed into water bodies following the application of water in firefighting.

6.2 Quantification of impact

Damage due to firefighting activities shall be assessed as soon as possible after an event and critical damage related to soils, vegetation and run-off quantified so that relevant remediation can be commenced.

6.3 Mitigation of impact

Both land-based and aerial application of firefighting chemicals shall be considered. Guidelines on the aerial application of firefighting chemicals near water are given in 5.3.3.

Progressive wildland fire plans incorporate methodology to ensure a balanced strategy with due consideration to minimizing the impact of firefighting tactics. Some examples of tactics that can reduce the impact of firefighting activities on the environment are listed below[10].

— Use natural barriers when possible.

— Use minimum fire line width and depth to accomplish the task.

— Avoid heavy equipment in riparian areas and meadows.

— Minimize felling of live trees and solid snags.

— Use natural openings for staging areas and camps.

— Employ "leave no trace" camping.

— Avoid the spread of non-native plants.

— Do not drop retardant or other suppressants near surface water.

— Use folding water tanks.

Following the requirements of the FLAME Act of 2009, the US Department of Agriculture published a National Cohesive Wildland Fire Management Strategy that uses a risk assessment approach to ensure that fire management decisions are based on the best available science, knowledge, and experience on a regional basis. This national strategy includes elements concerned with protection of the wildland environment, balanced with other concerns such as protection of lives and property[59].

Annex A
(informative)

Wildland fire incidents and their environmental impact

A.1 General

Certain high-hazard areas of the world have experienced recurring severe wildland fires throughout recorded history. These fires may have been caused by naturally occurring phenomena such as lightning or they could be the result of human activities. In some cases, the effects of wildland fires could be considered a beneficial part of the ambient environment, however, wildland fire effluent can also be a threat to the health of people and other organisms, as well as the earth's natural resources.

Every year there are more wildland fire incidents, especially in the high-hazard areas, that make a significant impact upon the environment. The wildland fire incidents listed below were chosen to highlight specific aspects of their impact on the environment.

A.2 Indonesian fires, 1997 and 2015

Between April and November 1997, a series of forest fires in Indonesia—particularly in Sumatra and Kalimantan—produced a thick, smoky haze which covered a large portion of Southeast Asia. These fires were the result of changes in land use involving logging and draining swamps and peatlands to make rice paddies. An estimated 0,8 Gt to 2,5 Gt of carbon were released into the atmosphere, which is 13 % to 40 % of the mean annual global carbon emissions from fossil fuels[60]. The smoke from the fires reached southern Thailand and the Philippines. The most severe effects were felt in Singapore, Malaysia, Brunei, and Indonesia. About 70 million people lived in areas affected by the smoke haze[44]. In 2015, under similar drought conditions, another series of large forest fires occurred in the same general area. These fires also affected air quality in Southeast Asia and released large quantities of carbon into the atmosphere[61]. It is unclear how these fires can be prevented unless changes in land use practices and enforcement are implemented.

A.3 Victorian Alpine fires, Australia, 2003

The 2003 alpine fires, caused by lightning, burnt over 25 % of the Murray River's Victorian catchment and are estimated to have resulted in at least a 10 % reduction in river flows[62]. A total of 1,73 million hectares was burned and two endangered species, the Corroboree frog and the mountain pygmy possum, were affected[63]. After several years of monitoring, Williams, et al. found that the flora and fauna of this region are highly resilient to infrequent, large, intense fires[64].

A.4 Russia, 2004

In the Russian Far East, strong repetitious burns in one region led to gradual replacement of rich uneven-aged mixed Korean pine-dominated forests by simple larch communities. In another region, multiple ground fires, which developed mainly because of agricultural burns, led to substitution of mixed forests with Korean pine (*Pinus koraiensis*) and Manchurian fir (*Abies holophylla*) by simpler deciduous communities dominated by Mongolian oak (*Quercus mongolica*)[37].

A.5 Greece fires, 2007 and 2009

The 2007 forest fires in Greece broke out in several areas. The fires mainly affected southern Greece. The environmental damages were heavy. Given the size of the burnt area, soil erosion and flooding potential were much heavier than ever before. Wildlife would have difficulty finding refuge and food. Seed sources for non-fire adapted species were often many kilometres away and would have resulted in changes in vegetation composition[65].

In 2009 a series of large forest fires burned in the suburban region northeast of Athens. Firefighting efforts to contain the spread of the fires were hampered by the need to protect homes and property, which had been built in “illegal ribbon development” schemes created for political reasons[66]. About half of the of the burned forest is expected to recover. These fires prompted new legislation to ban construction in parts of Greece until comprehensive forest maps have been created[67].

A.6 Waldo Canyon fire — Colorado, 2012

Starting in June, 2012, near Colorado Springs, the Waldo Canyon fire burned intensely and spread quickly in erratic wind conditions, causing the evacuation of 32 000 people and making it difficult to predict[68]. The fire burned through five major watershed areas, destroyed soil and vegetation to a depth of 100 mm in about 20 % of the burn area[69]. Efforts to prevent or mitigate further damage caused by erosion and flash flooding included construction of sediment catch basins, improving drainage structures, and stabilising slopes with straw and mulch[70].

A.7 Fort McMurray fire — Canada, 2016

The Fort McMurray fire started in May 2016 and burned for over a year, forcing the evacuation of 88 000 people in Alberta, Canada[71]. Oil sands mining operations in the area were temporarily scaled back, contributing to a global rise in oil prices[72]. This fire spread caustic ash containing heavy metals, PAHs, dioxins and furans through the region, contaminating soil and structures[73].

A.8 Thomas Fire — California, 2017

The Thomas Fire became the largest wildland fire in California to date, burning parts of Santa Barbara and Ventura counties in December 2017[74]. The onshore “Santa Ana” winds were particularly strong for this time of year and were a significant factor in the development of the fire. In addition to reduction of air quality due to smoke during the fire, heavy rain after the fire caused flash floods and massive erosion and mud/debris flows that damaged creeks and destroyed homes[75].

Annex B
(informative)

Airborne combustion products identified from wildland fires

B.1 General

Many works have studied the combustion products from wildland fires. A compilation of some reported combustion products is given in Table B.1.

Table B.1 — Airborne combustion products identified from wildland fires

Combustion product	Comments
CO_2	The highest airborne combustion product by mass[76]
CO	The second highest airborne combustion product by mass[76]
Particulate matter (PM_{10})	The third highest airborne combustion product by mass[76]
$PM_{2.5}$	Prescribed burning is a significant source of $PM_{2.5}$[23]
Dioxins	Levels measured in field trials were lower than expected from laboratory experiments[77] Smouldering of CCA-treated wood produces dioxins, but only small amounts survive continued combustion[78]
Hydrocarbons	Substantial quantities; includes methane[76]
Aldehydes	Formaldehyde is the predominant aldehyde[79]

Annex C
(informative)

Firefighting chemical additives and their environmental impact

C.1 General

Firefighting chemicals used in wildland fires are either long-term retardants or short-term retardants. In long term retardants the active ingredients are generally in aqueous solutions. Short-term retardants are applied as firefighting foams. Adams and Simmons[26] give a good overview of the major firefighting chemicals and their ecological impact. The data in Tables C.1 and C.2 come from this paper, unless otherwise referenced.

Table C.1 — Firefighting chemicals

Retardant[1]	Composition[2]	Type
Phos-Chek D75-F	diammonium sulphate, diammonium phosphate, monoammonium phosphate, thickeners, colours and preservatives	long-term – aerial application
Phos-Chek D75-R	diammonium sulphate, diammonium phosphate, monoammonium phosphate, thickeners, colours and preservatives	long-term – aerial application
Fire-Trol GTS-R	diammonium sulphate, diammonium phosphate, monoammonium phosphate, thickeners, colours and preservatives	long-term – aerial application
Fire-Trol 934	ammonium polyphosphates, no thickeners or colours	long-term – manual application
Ansul Silv-Ex	surfactants, foaming agents, wetting agents	short-term (foam)
Angus ForExpan S	surfactants, foaming agents, wetting agents	short-term (foam)
Fire Quench	surfactants, foaming agents, wetting agents	short-term (foam)
3M Firebreak	surfactants, foaming agents, wetting agents	short-term (foam)
Phos-Chek WD-881	surfactants, foaming agents, wetting agents	short-term (foam)

1 These fire retardants are examples of products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

2 All contain about 85 % water as applied.

Table C.2 — Environmental effects of firefighting chemicals

Chemical	Environmental effects
diammonium phosphate	grassland can increase biomass; legumes may fail to establish[26]
ammonium sulphate	leaf death can occur in eucalypts and angophora[26]
surfactants	in humans, exposure to the skin may cause mild to severe chapping, and mild to severe irritation of the eyes; in fish, surfactant in the water interferes with the ability of gills to absorb oxygen from the water and can cause the fish to suffocate[29]
sodium ferrocyanide (corrosion inhibitor)	may pose a toxic threat to aquatic species and aquatic environments[32]

Annex D
(informative)

Impact of climate change

Fire risk depends on many factors, including climatic conditions, vegetation, forest management practices and other socio-economic factors. Climate change alters the frequency and severity of wildland fires, and hence alters their environmental impact[80]. It also leads to changes to the nature and distribution of forests, and results in more smoke emission[81].

According to the European Environment Agency[82] the burnt area in the Mediterranean region of Europe increased from 1980 to 2000 but has decreased after that. In a warmer climate, more severe fire weather and, as a consequence, an expansion of the fire-prone area and longer fire seasons are projected across Europe. Climate change projections suggest substantial warming and increases in the number of droughts, heat waves and dry spells across most of the Mediterranean area and more generally in southern Europe. These projected changes would increase the length and severity of the fire season, the area at risk and the probability of large fires, possibly enhancing desertification[83].

Researchers in China have found a correlation between climate change and wildland fires caused by cloud-to-ground lightning. These lightning-induced fires are sensitive to the daily minimum temperature and thus, as this temperature increases, the number of wildland fires is also expected to increase[84].

Areas that have previously not been seriously affected by wildland fire can become fire-prone due to climate change. An example of this phenomenon is the tropical mountain cloud forests and puna grasslands of South America[85].

Bibliography

[1] ISO Guide 64, *Guide for addressing environmental issues in product standards*

[2] AFAC. *Bushfire Glossary.* Australasian Fire Authorities Council, Melbourne, Australia, 2012

[3] NFPA. *Standard for Reducing Structure Ignition Hazards from Wildland Fire, NFPA 1144.* National Fire Protection Association, Quincy: 2013

[4] Sandberg D.V., Ottmar R.D., Peterson J.L., Core J. 2002, Characterization of Emissions from Fires, In Wildland Fire in Ecosystems – Effects of Fire on Air, US Department of Agriculture Forest Service General Technical Report RMRS-GTR-42- volume 5, 79 pp

[5] Myronidis D., & Arabatzis G. 2009, Evaluation of Greek Post-Fire Erosion Mitigation Policy through Spatial Analysis. *Pol. J. Environ. Stud.* 2009, **18** (5) pp. 865–872

[6] Neary D.G., Landsberg J.D., Tiedemann A.R. And Ffolliott, P. F. 2005, Water Quality, In Wildland Fire Ecosystems – Effects of Fire on Soil and Water, US Department of Agriculture Forest Service, General Technical Report RMRS-GTR-42-volume 4, Chapter 6

[7] GAO. 2004, Wildland Fires, Forest Service and BLM Need Better Information and a Systematic Approach for Assessing the Risks of Environmental Effects, United States General Accounting Office, Report to Congressional Requesters, GAO-04-705, Washington, D.C., USA

[8] Brotak E. 2011, Wildfires make their own weather, Aerosafety World, Feb., 35-37

[9] Staddon W.J., Duchesne L.C., Trevors J.T. Impact of clear-cutting and prescribed burning on microbial diversity and community structure in a Jack pine (Pinus banksiana Lamb.) clear-cut using Biolog Gram-negative microplates. *World J. Microbiol. Biotechnol.* 1998, **14** (1) pp. 119–123. DOI:0.1023/A:1008892921085

[10] Backer D.M., Jensen S.E., McPherson G.R. Impacts of Fire-Suppression Activities on Natural Communities. *Conserv. Biol.* 2004, **18** (4) pp. 937–946

[11] Pettenella D. 2009?, Proposal for a Harmonized Methodology to assess Socio-economic Damages from Forest Fires in Europe, Dipartimento di Scienze e Tecnologie per l'Ambiente e il Territorio Università degli Studi del Molise, Contrada Fonte Lappone 86090 Pesche (IS), Italy, Contract 383443 F1SC

[12] Santoni P.-A. 2012, University of Corsica, private communication

[13] Meyer C.P. 2005, Dioxin Emissions from Broad Scale Biomass Burning in Australia. Proceedings 17th International Clean Air & Environment Conference (M. Hooper and P. Holmes Eds), Hobart, Australia, (1-6). 3-6 May

[14] Lighty J.S., Veranth J.M., Sarofim A.F. Combustion aerosols: factors governing their size and composition and implications to human health. *J. Air Waste Manage. Assoc.* 2000, **50** pp. 1565–1618 [Cited in: Bravo, A. H. et al 2002, Impact of wildfires on the air quality of Mexico City, 1992–1999, Environmental Pollution **117**, 243–253]

[15] Bravo A.H. Impact of wildfires on the air quality of Mexico City, 1992–1999. *Environ. Pollut.* 2002, **117** pp. 243–253

[16] Christopher S.A., Wang M., Berendes T.A., Welch R.M., Yang S.K. 1985 biomass burning season in South America: satellite remote sensing of fires, smoke, and regional radiative energy budgets. *J. Appl. Meteorol.* 1998, **37** (7) pp. 661–678

[17] Blomqvist P., Persson B., Simonson M. Fire Emissions of Organics into the Atmosphere. *Fire Technol.* 2007, **43** pp. 213–231

