
**Guidelines for assessing the adverse
environmental impact of fire
effluents —**

**Part 3:
Sampling and analysis**

*Lignes directrices pour déterminer l'impact environnemental des
effluents du feu —*

Partie 3: Échantillonnage et analyse

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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*.

A list of all parts in the ISO 26367 series can be found on the ISO website.

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

Pollution of indoor and outdoor environments by complex mixtures of physical and chemical combustion products is a causative agent of human health and environmental problems on a global scale. Uncontrolled and incomplete combustion processes are responsible for the emission of chemical and physical pollutants in quantities that affect humans and the environment.

General awareness of the fact that fires can present dramatic and persistent adverse effects on the environment has been accentuated by a number of high-impact incidents over the past half century as exemplified in ISO 26367-1. The serious consequences of such events have confirmed that the environmental impact of fires is an important issue that needs to be dealt with internationally and systematically. The ISO 26367 series provides a framework for a common treatment of the environmental impact of fires in answer to this pressing need.

This document provides references to methods for sampling and analysis of fire effluents from environmentally significant fires. It is important to understand the chemical and physical nature of the components of the fire effluents, including their concentration within the fire plume and within different recipients. It is also necessary to determine the natural levels of the same pollutants in the affected area(s) in order to establish a baseline for measurement of the environmental impact of the fire.

With fires that primarily have the potential to harm the environment it is likely that there will be fewer logistical restraints for obtaining samples from the fire effluent than those from life-threatening fires. For example, these fires can be relatively large and less confined, compared to their mainly life-threatening counterparts. The fire plume can extend for many kilometres and can deposit particles and associated chemical species over a wide area. The fire residues can contaminate the soil and as run-off, contaminate surface and groundwater courses. Sampling, although unlikely to be straightforward, is therefore feasible with standard techniques and trained personnel.

In many cases, the sampling and analysis of compounds having the potential to harm the environment have been well-documented. This document therefore provides a guide to the “best practice” methodologies for sampling and analysing specific compounds that could be present in fire effluents. The compounds and the concentration levels of interest are dependent on the goals of the user and could be outside of the limits of the recommended sampling and analysis methods referenced in this document.

A methodology for compiling the information needed to assess the environmental damage caused by a fire incident and the establishment of data quality objectives and the design of sampling programmes is included in ISO 26367-2. It also provides a standardized method for reporting the results of the compilation and findings of the analyses for use in contingency planning or for the assessment of the potential adverse environmental impact of a specific fire incident.

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Guidelines for assessing the adverse environmental impact of fire effluents —

Part 3: Sampling and analysis

1 Scope

This document is applicable to the sampling and analysis of effluents produced during fires that have the potential to cause harm through environmental contamination. It provides additional requirements to those International Standards already published by ISO TC 92/SC 3 for the sampling and analysis of fire effluents from experimental fires and standard tests, specifically as best practice from previously published methodologies. This document does not include pollutant screening of exposed humans or animals.

The principle aims for the sampling and analysis of effluents from fires that can result in environmental contamination is therefore to provide information on:

- the nature and concentrations of airborne effluents over time and distance;
- the nature and concentrations of solid and liquid ground contaminants and “run-off” compounds from firefighting operations over time and distance.

This document is principally of interest for the following parties:

- environmental regulatory authorities;
- public health authorities;
- fire investigators;
- property owners.

This document is intended to be used together with ISO 26367-1 and ISO 26367-2 in assessments of the environmental impact of fire effluents.

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 3941, *Classification of fires*

ISO 13943, *Fire safety — Vocabulary*

ISO 14050, *Environmental management — Vocabulary*

ISO 19258, *Soil quality — Guidance on the determination of background values*

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

ISO 26367-2:2017, *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 3941, ISO 13943, ISO 14050, ISO 26367-1 and ISO 26367-2 and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 background concentration

concentration of a substance characteristic of an environmental phase in an area or region arising from both natural sources and non-natural diffuse sources, such as atmospheric deposition

Note 1 to entry: Commonly expressed in terms of average, typical median, a range of values or a background value.

[SOURCE: ISO 11074:2015, 3.5.1,^[1] modified — “soil type” has been replaced with “environmental phase”.]

3.2 continuous measurement

measurement obtained by taking a sample continuously with simultaneous or slightly delayed analysis

[SOURCE: ISO 11665-1:2019, 3.1.8,^[2] modified — the phrase “(or at integration intervals typically in the range of 1 min to 120 min)” has been removed. Notes to entry 1 and 2 have been removed.]

3.3 extractive sampling

extraction of the sample, removal of interfering materials and maintenance of gas concentration throughout the sampling system for subsequent analysis by appropriate instrumentation

[SOURCE: ISO 11042-2:1996, 3.4.1,^[3] modified — figure removed.]

3.4 in situ measurement

direct measurement of the measurand in its original place

Note 1 to entry: Measurand means substance of interest.

[SOURCE: ISO/TS 19159-1:2014, 4.11,^[4] modified — Note 1 to entry added.]

3.5 open-path measurement

measurement where the light beam of an optical method is directed across the effluent in its original place

Note 1 to entry: An example of an optical method is FTIR.

4 Abbreviated terms

BOD	biological oxygen demand
COD	chemical oxygen demand
DQO	data quality objective
FTIR	Fourier transform infrared (spectroscopy)

GC-ECD	gas chromatography-electron capture detector
GC-MS	gas chromatography-mass spectroscopy
HX	halogenated acids
ICP-OES	inductively coupled plasma-optical emission spectroscopy
LC/MS/MS	liquid chromatography/mass spectroscopy/mass spectroscopy
LIDAR	laser induced differential absorption radar
NO _x	nitrogen oxides
OP-FTIR	open path-FTIR
PAH	polycyclic aromatic hydrocarbons
PBDD	polybrominated dibenzodioxins
PBDF	polybrominated dibenzofurans
PBB	polybrominated biphenyls
PCB	polychlorinated biphenyls
PCDF	polychlorinated dibenzofurans
PCDD	polychlorinated dibenzodioxins
PFC	perfluorinated compounds
PFAS	per- and polyfluorinated alkylated substances
POP	persistent organic pollutant
SVOC	semi-volatile organic compounds
VOC	volatile organic compounds
XRF	X-ray fluorescence (spectroscopy)

5 Indicators and pollutants

Pollutants that either typically occur as a result of fire or are particularly harmful to the environment are listed in ISO 26367-2 and are also given here in [Tables 1](#) to [3](#) for convenience. In some cases, other species should be considered, depending on the suspected substances in the fuel. ISO 26367-2:2017, Clause 6 shall be followed for the selection of indicators and pollutants to analyse.

Fire effluents can produce adverse environmental impacts that are not directly associated with specific pollutants but are indicated by the effects they produce. The properties listed in [Table 1](#) represent general indicators of environmental pollution and the relevant environmental phase in each case.

Specific pollutants can be associated with short-term adverse effects or long-term adverse effects on the environment, or both. The pollutants listed in [Table 2](#) are associated with short-term effects and the pollutants listed in [Table 3](#) are associated with long-term effects. The relevant environmental phase is also given in these tables.

Table 1 — Indicators of environmental pollution

Indicator	Environmental phase
Alkalinity	Surface water, groundwater, sediment, soil
Biological oxygen demand (BOD)	Surface water, groundwater, sediment
Chemical oxygen demand (COD)	Surface water, groundwater, sediment
Electrical conductivity	Surface water, groundwater, sediment, soil
Hydrocarbon (oil) screening	Surface water, groundwater, sediment, soil
pH	Surface water, groundwater, sediment, soil
Turbidity	Surface water, groundwater
Water quality (e.g. luminescent bacteria)	Surface water

NOTE Oil is often used as a screening parameter for contaminated areas. There are different screening methods that include different ranges of hydrocarbons.

Table 2 — Pollutants associated with short-term adverse effects on the environment

Pollutant	Environmental phase
Halogenated acids (HX)	Air
Metals	Air, surface water, groundwater, sediment, soil
Nitrogen oxides (NO _x)	Air
Particulates	Air, deposition on surface water and soil
Sulfur oxides	Air
Volatile Organic Compounds (VOC)	Air

NOTE Additional background information is provided in ISO 26367-2 on pollutants having short-term effects.

Table 3 — Pollutants associated with long-term adverse effects on the environment

Pollutant	Environmental phase
Metals	Air, surface water, groundwater, sediment, soil
Particulates	Air, deposition on surface water and soil
Perfluorinated compounds (PFC) ^a	Surface water, groundwater, sediment, soil
Polychlorinated biphenyls (PCB)	Air, deposition on surface water and soil, sediment
Polychlorinated dibenzodioxins (PCDD) ^b	Air, deposition on surface water and soil, sediment
Polychlorinated dibenzofurans (PCDF) ^b	Air, deposition on surface water and soil, sediment
Polycyclic aromatic hydrocarbons (PAH)	Air, deposition on surface water and soil
Volatile organic compounds (VOC) ^c	Air, surface water, groundwater, sediment, soil

^a Analysis of a broader spectrum of PFAS compounds (perfluorinated and polyfluorinated substances) might be relevant in a detailed investigation.

^b Polybrominated dibenzodioxins (PBDD), polybrominated dibenzofurans (PBDF) and mixed chlorine/bromine dioxin-furan congeners shall be analysed if the fuel load has a significant bromine content, for example in the case of materials containing brominated flame retardants.

^c Semi-volatile organic compounds (SVOC) might be relevant to analyse in a detailed investigation. This class of compounds include plasticisers (phthalates) and some fire retardants (e.g. polybrominated biphenyls, PBB).

NOTE Additional background information is provided in ISO 26367-2 on pollutants having long-term effects.

6 Sampling requirements

6.1 General

The process for determining the overall sampling design begins with identifying data quality objectives (DQOs), which are used throughout the sampling and analysis process to ensure that the results are of

sufficient quality to satisfy the needs of the project. The steps involved in establishing DQOs described in ISO 26367-2:2017, Clause 5 shall be followed.

NOTE The framework for recording the steps taken to collect and treat data are provided in ISO 26367-2:2017, Clauses 6 and 7, including compiling the contaminants of interest, recording all relevant information and analysing the usability of the data. This document also includes a flow diagram showing the steps and indicating a structure for the sampling process.

Representative background concentrations shall be analysed in all cases to be used as a basis for the assessment of pollution levels.

The requirements in the following clauses assume that the procedures given in ISO 26367-2 have been implemented.

6.2 Personnel requirements

Individuals performing the sampling work should be environmental professionals or should work under the responsible supervision of an environmental professional.

NOTE An environmental professional is defined as a person having relevant competencies recognized by authorities having jurisdiction in the region of the work.

6.3 Sampling techniques

6.3.1 General

The equipment and techniques required to analyse pollutant samples are dependent on the environmental phase (air, surface water, groundwater, sediment or soil) and on whether the analysis takes place by in situ measurement or in a laboratory. They are also dependent on the nature of the chemical compound or species of interest.

In the following subclauses the sampling apparatus and techniques are grouped primarily by phase (gas, liquid, solid) and secondarily by groups of compounds typically found in these phases. Many compounds and species are emitted into multiple phases as fire effluent or are transported across phase boundaries over time.

NOTE Information on specific sampling requirements for individual pollutants is given in the respective subclause on sample analysis.

6.3.2 Fire plume sampling

Direct sampling of emissions to the air can only be made when the fire is ongoing. Airborne sampling from a variety of aircraft has been reported;^[5, 6] however, it is unclear how such point samples can be related to ground deposition.

General standards for air sampling include ISO 9359^[7] (stratified sampling method), ISO 7168-1^[8] and ISO 7168-2^[9] (both on exchange of air quality data).

Fire plume sampling or sample collection procedures shall be conducted in accordance with standardized methods; such methods are included in ISO 19701^[10], ISO 19702^[11] and ISO 29904^[12]. The techniques described in ISO 19701 and ISO 19702 were developed to analyse higher concentrations in smoke. When they are used for environmental purposes, users should consider specific requirements for short-lived species and also limits of quantification and range of concentrations.

6.3.3 Liquid phase sampling

Emissions to the aquatic environment can affect both surface and ground water. Transport of fire effluent to the aquatic environment can occur through deposition of airborne contaminants onto soil or water surfaces or from fire water run-off that carries extinguishing media and/or residue from the fire ground. The location and nature of sampling shall be based on the knowledge of the pathway by

which fire water run-off spreads into the environment and the area over which atmospheric deposition is observed or predicted to have occurred.

A detailed post-incident analysis of pathways shall be conducted to reveal all potential or actual routes to receptors.

Information on environmental damage limitation by collection of fire water run-off is given in ISO/TR 26368.^[13]

Liquid samples shall be collected in accordance with standardized methods; such methods include ISO 5667-1^[14] (sampling programme and techniques), ISO 5667-10^[15] (waste water), ISO 5667-11^[16] (groundwater), and ISO 5667-6^[17] (rivers and streams).

6.3.4 Solid phase sampling

6.3.4.1 Soil sampling

Emissions can impact the terrestrial environment. Samples shall be taken of soil at least in the downwind direction from the fire in the path of the fire plume and in an area free of deposit to provide a reference sample. To determine the most relevant zones for sampling, an atmospheric dispersion and deposition model^[18,19,20] may be used. This model should integrate the characteristics of the wind, direction and intensity, for the whole period of the fire. When no information is available about the wind direction and intensity, sampling should be done all around the fire up to several kilometres from the fire.

Solid phase sample collection procedures shall be conducted in accordance with standardised methods; such methods include ISO 10381-1^[21] (sampling programmes), ISO 10381-2^[22] (soil), ISO 10381-5^[23] (urban and industrial sites), ISO 5667-12^[24] (sediments) and ISO 5667-1^[11] (sampling programme and techniques for sludges and bottom deposits).

NOTE 1 ISO 18400-102^[25] gives general information on the selection and application of sampling techniques for soil.

NOTE 2 ISO 19204^[26] specifies a procedure for a site-specific ecological risk assessment of soil contamination.

6.3.4.2 Plants and farm products

Analysis of plants and farm products can provide an indication of adverse environmental impact from fire due to bioaccumulation of pollutants.^[27] The sampling method depends on the type of exposure to plants in agricultural land, for example direct contamination by gases or particles, or indirect contamination by irrigation water.

Plant or crop sampling should be done with the plant or crop as it is at the time of the event or incident to establish a benchmark. Sampling can continue in the future as the plant grows or matures.

Regarding sampling of plants, it is important to:

- sample the plants in their commonly used vegetative state;
- avoid sampling during a water stress period;
- avoid sampling soiled plants;
- sample representative plants, not only the most healthy specimens.

Plant samples shall be separated from soil to prevent delayed contamination. The sample mass shall be measured during the sampling process. This is especially important for plants that are sensitive to humidity losses. Conditions for transport shall be designed to prevent damage, e.g. crushing. The laboratory analysis method shall be chosen in accordance with the pollutants to be measured.

If agricultural land is located within the fire plume deposition zone, specific farm products can be sampled and analysed as indicators of environmental impact. For example, milk and eggs are useful for delayed sampling since the transfer time for contaminants to these products is longer than the transfer time to plants.^[27]

NOTE Fertilizers made from sewage sludge can be used in agriculture, thus contaminating the food supply for animals and people. The contamination with POPs is of special concern, for example PFAS from firefighting foams.^[28] However, in some areas sewage sludge is assessed and shown to have contaminants below regulated levels before it can be used on the field.

7 Sample storage and handling

7.1 General

Information on specific storage and handling requirements for individual pollutants is given in the respective subclause on sample analysis.

7.2 Gases and vapour

Gas and vapour phase samples shall be stored and handled in accordance with standardized methods to preserve the sample quality; such methods are included in ISO 16017-1^[29] (air - pumped sampling of VOC, thermal desorption), ISO 16017-2^[30] (air - diffusive sampling of VOC, thermal desorption), ISO 16200-1^[31] (air - pumped sampling of VOC, solvent) and ISO 16200-2^[32] (air - diffusive sampling of VOC, solvent).

NOTE Accumulative air sampling is often of the type where specific pollutants are trapped on an adsorbent material or in a sampling liquid. In these cases, the principal preservation method is to store the sample at a low temperature in a refrigerator or freezer.

7.3 Particulates and aerosols

Particulate and aerosol samples shall be stored and handled in accordance with standardized methods to preserve the sample quality; such methods are included in ISO 23210^[33] and ISO 13271^[34] (impactor measurements).

7.4 Liquid phase

Liquid phase samples shall be stored and handled in accordance with standardized methods; such methods are included in ISO 5667-3.^[35]

7.5 Solid phase

Solid samples shall be stored and handled using standardized procedures to preserve the sample quality; such methods are included in ISO 10381-1,^[21] ISO 10381-2,^[22] ISO 18512^[36] (soil) and ISO 5667-15^[37] (sludge and sediment).

Solid phase includes soil, sediments, deposition and fire residue. The applicability of cited standardized methods shall be confirmed before application.

NOTE Information on analysis and sample handling of fire residues can be found in Reference ^[38].

8 Sample analysis

8.1 General

There are a large number of analysis techniques for quantifying the concentration of compounds in the environment. Some analysis techniques, such as ISO 17155,^[39] address ecotoxicity in a general sense.

These analysis techniques measure the effects of the contamination on the environment rather than concentrations of specific chemicals. Other techniques are chemical specific, such as ISO 11885.^[40] Other analysis techniques are designed to measure the concentration of congeners of a certain type of compound such as polycyclic aromatic hydrocarbons (PAHs) or polychlorinated dibenzodioxins (PCDDs).

The exact analysis of the samples collected will depend on the fuel composition and the likely breakdown products. The procedures given in ISO 26367-2 shall be followed for determining appropriate analyses.

Chemical speciation shall be considered when selecting the analysis method for a pollutant.

NOTE Chemical speciation is of relevance for metals and cyanides, for example.

8.2 Gases and vapours

8.2.1 General

Analysis of air contamination shall be made using standardized extractive continuous measurement methods or open-path optical methods, or by laboratory analysis of extractive collected air samples. Appropriate general methods for compounds in fire effluents are given in ISO 19701 (general document on analysis of fire gases) and ISO 19702 (specific on FTIR analysis). The techniques described in ISO 19701 and ISO 19702 were developed to analyse higher concentrations in smoke. When they are used for environmental purposes, users should consider the limits of quantification and the range of concentrations.

NOTE ASTM E800-07 is another useful general document on the analysis of fire gases.^[41]

8.2.2 General atmospheric pollutants

Analysis shall be conducted in accordance with standardized methods. For halogenated acids (HX), nitrogen oxides (NO_x) and sulfur oxides, methods are given in ISO 19701^[10] for wet chemical laboratory analysis.

Methods for analysing halogenated acids (HX), nitrogen oxides (NO_x) and sulfur oxide, using extractive FTIR measurement methods, are given in ISO 19702.^[11]

Open-path optical techniques can be used for direct analysis of air concentrations of some pollutants. These techniques have most frequently been used in wildland fires, for example OP-FTIR measurements of trace gas emissions from Australian forest fires.^[42] Different open-path measurement techniques may be used depending on the objective. Most applied analysis techniques include open-path IR analysis of gas species^[43-46] and long-range LIDAR for scanning of aerosol clouds.^[47]

8.2.3 Organic pollutants

8.2.3.1 General

Analysis shall be conducted in accordance with standardized methods. Methods for analysis of the organic pollutants referred to in [Table 3](#) are given in [8.2.3.2](#) to [8.2.3.5](#).

8.2.3.2 Volatile organic compounds (VOC)

Sampling and analysis shall be made in accordance with standardised methods; such methods include ISO 16200-1^[31] (pumped sampling, solvent desorption and GC-analysis), ISO 16200-2^[32] (diffusive sampling, solvent desorption and GC-analysis), ISO 16017-1^[29] (pumped sampling, thermal desorption and GC-analysis) and ISO 16017-2^[30] (diffusive sampling thermal desorption and GC-analysis).

NOTE Methods for some specific VOCs are available in ISO 19701 (e.g. HPLC-analysis for phenol, benzene, toluene and styrene).

8.2.3.3 Polycyclic aromatic hydrocarbons (PAH)

Sampling and analysis shall be made in accordance with standardized methods; such methods include ISO 12884^[48] (gas and particle-phase PAHs with GC-MS analysis) and ISO 16362^[49] (particle-phase PAHs with HPLC analysis).

8.2.3.4 Polychlorinated dibenzodioxins and furans (PCDD/PCDF)

Sampling and analysis shall be made in accordance with standardized methods; such methods include EN 1948-1^[50] (sampling and sample storage), EN 1948-2^[51] (extraction and clean-up of samples) and EN 1948-3^[52] (analysis of samples).

NOTE Polybrominated dibenzodioxins and furans (PBDD/PBDF) and mixed chlorine/bromine dioxin-furan congeners are sampled and analysed using the same basic methods as used for PCDD/PCDF, although standardized methods have not been found.

8.2.3.5 Polychlorinated biphenyls (PCB)

Sampling and analysis shall be made in accordance with standardized methods; such methods include ISO EN 1948-4^[53] (dioxin-like PCBs).

8.2.4 Metals and elements

Most metals are not present in gaseous form in fire plumes. They are usually present in particulate form or associated with particulates (see 8.2.5). A few metals are more likely to be present in gaseous form, e.g. mercury (Hg).

Sampling and analysis shall be made in accordance with standardized methods; such methods include ISO EN 15852^[54] (determination of gaseous mercury) and ISO 19701 (sampling and analysis of antimony [Sb] and arsenic [As] in fire atmospheres).

NOTE The sampling and analysis methods in ISO 19701^[10] include sampling with a fritted bubbler containing 1 M hydrochloric acid for capturing and keeping metal ions in the solution. In order to also include metals in particulate form, the bubbler can be preceded by a filter which is desorbed with a strong HCl solution prior to AAS or ICP analysis. Other metallic elements can also be trapped by the same test solution and analysed.

8.2.5 Particulates and aerosols

Aerosols generated in fires are complex, non-homogeneous mixtures of liquid droplets of tar or water, solid-phase carbonaceous agglomerated soot with adsorbed organic compounds or mineral particles.

NOTE Particles having a diameter of less than 10 µm are possible to inhale and the smaller the particle, the less probable it is that the defence system of the body (nose, throat) can prevent the material from reaching deep into the lungs. It has been shown that the health effect is related mainly to the sub-micron-sized fraction of the particles, i.e. to the particles having an aerodynamic diameter less than 1 µm.^[55]

Samples are normally collected for the determination of total particle mass (direct gravimetric method) or particle mass concentrations and particle size distributions (impactor methods).

Samples shall be analysed in accordance with standardized methods; such methods are included in ISO 29904^[12] (direct gravimetric and impactor methods), ISO 23210^[33] and ISO 13271^[34] (impactor measurements).

In some cases, specific compounds associated with particles are of interest to analyse. Such analyses shall be conducted in accordance with standardised methods. General information is given in ISO 29904. Specific analysis methods include EN 14902^[56] (Pb, Cd, As and Ni in PM10 fraction), EN 16913^[57] and CEN/TR 16269^[58] (standard and guide for analysis of anions and cations in PM2,5).

Non-extractive analysis techniques for aerosol particulates are based on open-path optical techniques such as light extinction (photometry), laser scattering or image processing. These methods are detailed in ISO 29904.^[12]

Asbestos is a family of mineral fibres that can be released from certain construction materials in fires. Standardised methods shall be used for the analysis of asbestos in air samples. Such methods include ISO 10312^[59] (determination of asbestos fibres in ambient air using direct-transfer transmission electron microscopy) and ISO 13794^[60] (indirect-transfer transmission electron microscopy).

8.3 Liquid phase

8.3.1 General

The exact analysis of the samples depends on the fuel composition and the likely breakdown products as well as any firefighting agent used.

Samples shall be analysed in accordance with standardized methods. In the following subclauses, methods are provided for the analysis of specific pollutants or indicative tests of pollution.

It can in many cases be advantageous to use screening methods or fast test kit methods to get qualitative information on the extent of pollution. ASTM D6850^[61] provides guidance for quality control of screening methods for organic and inorganic constituents in water. ISO 17381^[62] gives information on the use of a test kit method for water analysis, both in-field and in the laboratory.

NOTE The analysis methods referred to in the following subclauses are in some cases also applicable to sludges and sediments.

8.3.2 Indicators of environmental pollution

General indicator parameters of water quality are given in [Table 1](#). The analysis of these parameters shall be made using standardised methods.

Methods for alkalinity include ISO 9963-1^[63] (total alkalinity and composite alkalinity) and ISO 9963-2^[64] (carbonate alkalinity).

Methods for biologic oxygen demand, BOD, include ISO 5815-1^[65] (dilution and seeding method) and ISO 5815-2^[66] (method for undiluted samples).

Methods for chemical oxygen demand, COD, include ISO 6060^[67] (dichromate method for total COD) and ISO 15705^[68] (simplified closed tube method).

Methods for electrical conductivity include ISO 7888^[69] (all types of water).

Methods for pH include ISO 10523^[70] (all types of waters and watery sludge).

Methods for turbidity include ISO 7027-1^[71] (specifies methods for low- and high turbid waters).

NOTE Suspended materials in waters can be quantitatively determined using EN 872.^[72]

Hydrocarbon pollution can be indicated by a “hydrocarbon oil index”. The analysis shall be made using standardized methods; such methods include ISO 9377-2.^[73]

The measurement of the acute toxicity of waters to different control organisms can be assessed using standardized methods. Such methods include ISO 6341^[74] (Daphna magna test), ISO 7346-1^[75] (fish test) and ISO 15088^[76] (fish eggs).

8.3.3 Organic pollutants

8.3.3.1 Hydrocarbons

Several methods are available for analysis of VOCs in water. Samples shall be analysed in accordance with standardized methods; such methods include ISO 17943^[77] (head-space SPME fibre microextraction and GC-MS), ISO 20595^[78] (head-space extraction and GC-MS) and ISO 10301^[79] (methods for GC-analysis of halogenated hydrocarbons).

Methods for analysis of the total absorbable organically bound halogens (AOX) in water include ISO 9562^[80] (method for measurement of total organic halogens expressed as chloride).

8.3.3.2 Polycyclic aromatic hydrocarbons (PAH)

Sampling and analysis shall be made in accordance with standardized methods; such methods include ISO 17993^[81] (HPLC method for 15 PAHs) and ISO 28540^[82] (GC-MS method for 16 PAHs).

8.3.3.3 Polychlorinated dibenzodioxins and furans (PCDD/PCDF)

Sampling and analysis shall be made in accordance with standardized methods; such methods include ISO 18073^[83] (chlorinated dioxins and furans using HRGC/HRMS).

NOTE Polybrominated dibenzodioxins and furans (PBDD/PBDF) and mixed chlorine/bromine dioxin-furan congeners are analysed using the same basic methods as used for PCDD/PCDF, although standardized methods have not been found.

8.3.3.4 Polychlorinated biphenyls (PCB)

Sampling and analysis shall be made in accordance with standardized methods; such methods include ISO 17858^[84] (PCB analysis using GC-MS).

8.3.3.5 Perfluorinated compounds (PFC)

Sampling and analysis shall be made in accordance with standardized methods; such methods include:

ISO 25101^[85] for perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA) in drinking water and surface water (HPLC-MS/MS method).

EPA method 537^[86] for perfluorinated alkyl acids in drinking water (method for analysis of 14 perfluorinated alkyl acids).

NOTE EPA laboratories have tested an existing direct injection analytical protocol for preparing and analysing 24 PFAS analytes in groundwater, surface water and wastewater. This work was completed in 2017.

ASTM D7979^[87] for PFAS substances in water, sludge and wastewater (method for determination of 21 PFAS substances).

8.3.4 Metals and elements

Samples shall be analysed in accordance with standardized methods; such methods include ISO 17294-1^[88] (guidelines for ICP-MS analysis), ISO 17294-2^[89] (ICP-MS analysis of selected elements), ISO 11885^[90] (ICP-OES analysis of elements) and ISO 15586^[91] (analysis of trace elements).

NOTE ISO 15587-1^[92] and ISO 15587-2^[93] give guidance on digestion of samples before analysis.

8.4 Solid phase

8.4.1 General

The exact analysis of the samples depends on the fuel composition and the likely breakdown products.

ISO 19258 shall be applied for guidance on the determination of background values in soil analysis.

NOTE Methods for analysis of solid phase (soil) samples can in some cases also be applicable for samples of sediments and fire debris.

8.4.2 Indicators of environmental pollution

General indicator parameters of sediment and soil quality are given in [Table 1](#). The analysis of these parameters shall be made using standardized methods.

Methods for electrical conductivity include ISO 11265^[94] (analysis on water extracts of soil).

Methods for pH include ISO 10390^[95] (analysis on suspension of soil in water).

Hydrocarbon pollution can be assessed by screening methods. The analysis shall be made using standardized methods; such methods include ISO 16703^[96] (analysis of hydrocarbon content by GC).

The measurement of the acute toxicity of sediments and soil to different control organisms can be assessed using standardised methods. Such methods include ISO 11268-1^[97] (acute toxicity tests on worms) and ISO 11268-2^[98] (long-term toxicity on worms).

NOTE ISO 17616^[99] and ISO 15799^[100] give guidance on ecotoxicological characterization of soils.

8.4.3 Organic pollutants

8.4.3.1 Hydrocarbons

Samples shall be analysed in accordance with standardized methods; such methods include ISO 16703^[96] (GC screening), ISO 22155^[101] (GC analysis of selected: aromatics, halogenated hydrocarbons and ethers) and ISO 15009^[102] (GC method for volatile aromatics, naphthalene and volatile halogenated hydrocarbons).

8.4.3.2 Polycyclic aromatic hydrocarbons (PAH)

Samples shall be analysed in accordance with standardized methods; such methods include ISO 18287^[103] (GC-MS method for 16 PAHs) and ISO 13859^[104] (GC-MS/HPLC method for 16 PAHs, wide concentration range).

8.4.3.3 Polychlorinated dibenzodioxins and furans (PCDD/PCDF)

Analysis shall be made in accordance with standardized methods; such methods include ISO 13914^[105] (chlorinated dioxins, furans and dioxin-like polychlorinated biphenyls using GC/HRMS).

NOTE Polybrominated dibenzodioxins and furans (PBDD/PBDF) and mixed chlorine/bromine dioxin-furan congeners are sampled and analysed using the same basic methods as used for PCDD/PCDF, although standardized methods have not been found.

8.4.3.4 Polychlorinated biphenyls (PCB)

Analysis shall be made in accordance with standardized methods; such methods include ISO 10382^[106] (analysis using GC-ECD) and ISO 13876^[107] (analysis using GC-MS and GC-ECD).

8.4.3.5 Perfluorinated compounds (PFC)

Sampling and analysis shall be made in accordance with standardised methods; such methods include ASTM D7968^[108] (polyfluorinated compounds in solid sample matrix using LS/MS/MS).

8.4.4 Metals and elements

Analysis of metals and elements shall be made in accordance with standardized methods.

Methods for XRF-analysis of elemental contents include ISO 13196^[109] (screening for selected elements using portable instrument) and ISO 18227^[110] (laboratory method).

Methods for digestion and extraction of soil samples before analysis include ISO 11466^[111] (extraction with aqua regia), ISO 12914^[112] (MW-assisted extraction with aqua regia), ISO 16729^[113] (digestion with nitric acid) and ISO 17586^[114] (extraction of trace elements with nitric acid).

Methods for analysis sample composition include ISO 11047^[115] (selected elements by AAS), ISO 22036^[116] (trace elements by ICP-OES) and ISO/TS 16965^[117] (trace elements by ICP-MS).

8.4.5 Asbestos fibres

Asbestos fibres in solid materials such as fire debris shall be sampled and analysed using standardized methods. Such methods include the ISO 22262 series^[118-120] for quantitative analysis of asbestos fibres in bulk materials.

9 Calculation of effluent concentrations

To enable valid comparisons of fire effluents from varying scenarios and for the various purposes for which these data will be used it is essential that the concentrations of effluents (i.e. gases and vapours, particulates and aerosols, and residues) are obtained using standardised methods of calculation. Such calculations shall include quantification of sampling losses and sample storage effects in addition to the variability of the analytical method itself.

Information on standards, including specific storage and handling requirements for individual pollutants, is given in the respective clauses on sample analysis. Information on minimising or quantification of storage losses is in many cases given in these standards, for example ISO 18512^[36] and EN 1948-1.^[50]

10 Method validation and error quantification

Sampling and analysis shall be made using validated methods, such as those referred to in this document.

A quantification of the measurement uncertainty from the complete process from sampling to final analysis should be made if possible.

ISO 12828-2^[121] presents examples of complete method validation for fire effluents. ISO 20988^[122] provides more general guidelines for estimating measurement uncertainty and may be used for generic airborne pollutants. Water analysis uncertainties are described in ISO 11352.^[123]

11 Standard reporting requirements

The details for reporting the analysis results are provided in ISO 26367-2:2017, Clause 7. The intent and scope of the report, incident description, characterization of contaminant levels, discussion of results and findings are included in the reporting procedure. An example of a tabular reporting format that satisfies the requirements of ISO 26367-2 is also provided in ISO 26367-2:2017, Annex D.

Bibliography

- [1] ISO 11074, *Soil quality — Vocabulary*
- [2] ISO 11665-1, *Measurement of radioactivity in the environment — Air: radon-222 — Part 1: Origins of radon and its short-lived decay products and associated measurement methods*
- [3] ISO 11042-2, *Gas turbines — Exhaust gas emission — Part 2: Automated emission monitoring*
- [4] ISO/TS 19159-1, *Geographic information — Calibration and validation of remote sensing imagery sensors and data — Part 1: Optical sensors*
- [5] Luke et al. Trace gas measurements in the Kuwait oil fire smoke plume. *Journal of Geophysical Research Atmospheres*. 1992. <https://doi.org/10.1029/92JD00998>
- [6] Forster et al. Aircraft measurements over Europe of an air pollution plume from Southeast Asia – aerosol and chemical characterization. *Atmos. Chem. Phys.* 2007, 7 pp. 913-937. <https://doi.org/10.5194/acp-7-913-2007>
- [7] ISO 9359, *Air quality — Stratified sampling method for assessment of ambient air quality*
- [8] ISO 7168-1, *Air quality — Exchange of data — Part 1: General data format*
- [9] ISO 7168-2, *Air quality — Exchange of data — Part 2: Condensed data format*
- [10] ISO 19701, *Methods for sampling and analysis of fire effluents*
- [11] ISO 19702, *Guidance for sampling and analysis of toxic gases and vapours in fire effluents using Fourier Transform Infrared (FTIR) spectroscopy*
- [12] ISO 29904, *Fire chemistry — Generation and measurement of aerosols*
- [13] ISO/TR 26368, *Environmental damage limitation from fire-fighting water run-off*
- [14] ISO 5667-1, *Water quality — Sampling — Part 1: Guidance on the design of sampling programmes and sampling techniques*
- [15] ISO 5667-10, *Water quality — Sampling — Part 10: Guidance on sampling of waste water*
- [16] ISO 5667-11, *Water quality — Sampling — Part 11: Guidance on sampling of groundwaters*
- [17] ISO 5667-6, *Water quality — Sampling — Part 6: Guidance on sampling of rivers and streams*
- [18] World Meteorological Organization. *Dispersion models*. Updated 2014-05-02 [viewed 2021-09-08]. Available from: <https://community.wmo.int/dispersion-models>
- [19] McDermott R.J. et al. *Large Outdoor Fire Modeling (LOFM) Workshop Summary Report. NIST Special Publication 1245*. National Institute of Standards and Technology, 2019. Available from: <https://doi.org/10.6028/NIST.SP.1245>
- [20] Goodrick S.L. Modelling smoke transport from wildland fires: a review. *International Journal of Wildland Fire*. 22(1), 83-94. 2021. <https://dx.doi.org/10.1071/WF11116>
- [21] ISO 10381-1, *Soil quality — Sampling — Part 1: Guidance on the design of sampling programmes*
- [22] ISO 10381-2, *Soil quality — Sampling — Part 2: Guidance on sampling techniques*
- [23] ISO 10381-5, *Soil quality — Sampling — Part 5: Guidance on the procedure for the investigation of urban and industrial sites with regard to soil contamination*