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

**Part 2:  
Methodology for compiling data on  
environmentally significant emissions  
from fires**

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

*Partie 2: Méthodologie pour compiler les données relatives aux  
émissions des feux ayant un impact significatif sur l'environnement*





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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](http://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](http://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 on 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 the following URL: [www.iso.org/iso/foreword.html](http://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.

## 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. This problem is severe, not only in industrialized regions, but also in less developed, predominantly agricultural areas where people depend on biomass as fuel for cooking, heating and lighting.

General awareness of the fact that fires can present acute and persistent adverse effects on the environment has been accentuated by a number of high impact incidents over the past half century. [Annex A](#) contains a limited number of examples of emissions associated with various types of fires which could be expected to affect the environment adversely. These examples should not be considered as describing typical observations as fires and fire impacts are generally not comparable.

The serious consequences of such events have confirmed that the environmental impact of fires is an international issue that urgently needs to be dealt with globally and systematically. The ISO 26367 series of International Standards provides a framework for a common treatment of the environmental impact of fires in answer to this pressing need.

This document provides methods for the compilation of relevant data for assessing damage after a fire and for use in environmental fire hazard and risk assessments.

In view of the fact that relevant quantitative data on environmentally hazardous components of fire effluents cannot routinely be obtained from accidental fires, appropriate data may also be obtained from real-scale fire tests and simulations involving physical fire models.

The Sixth EC Environmental Action Programme, Environment 2010: Our Future, Our Choice spells out the objective of controlling levels of man-made chemicals so that they do not give rise to significant adverse impacts on human health or the environment<sup>[1]</sup>. In the case of eco-toxicity indicators, toxicity impact potential (TIP) characterization factors are used and are often developed using a multimedia environmental fate model to predict the movement and distribution of a given substance in environmental regions of interest<sup>[2]</sup>.

In the case of organohalogen compounds that are known to have natural as well as man-made sources, TIP characterization can be difficult, a fact acknowledged by the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) in quality status report, QSR 2000, as follows: “Many substances occur naturally in soils, plants and animals. It is therefore important to distinguish between the natural concentrations and fluxes of these substances and the extent to which they are augmented by human activities. Such distinctions are essential if informed decisions are to be made regarding the management of contaminants”<sup>[3]</sup>.

This document is principally intended for use by the following parties: environmental regulatory authorities, fire fighters and investigators, storage facility operators, materials and product manufacturers, property owners, and public health authorities.



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

## Part 2: Methodology for compiling data on environmentally significant emissions from fires

### 1 Scope

This document specifies a methodology for compiling the information needed to assess the environmental damage caused by a fire incident. This includes conducting a site reconnaissance, establishing data quality objectives and designing sampling programmes. This document 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. This document does not include specific instruction on sampling and analysis of fire effluents. Sampling and analysis are the focus of a future document in the ISO 26367 series.

This document is applicable to uncontrolled fires, including fires in commercial and domestic premises, unenclosed commercial sites, agricultural storage sites, wildland and forest fires, as well as fires involving road, rail and maritime transport systems.

This document focuses on the fire effluents that are environmentally significant, including pollutants causing short-term effects (e.g. pollutants causing biotope damage and components of smog) and long-term effects (e.g. persistent organic pollutants, POP). Since it is not possible to treat all potential pollutants that could be found in fire effluents in a single document, a list of those pollutants specifically addressed in this document is given below:

- a) pollutants with short-term effects: halogenated acids (HX), metals, nitrogen oxides (NO<sub>x</sub>), particulates, and sulfur oxides (SO<sub>x</sub>);
- b) pollutants with long-term effects: metals, particulates, perfluorinated compounds (PFC), polyaromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and polyhalogenated dioxins and furans (PXDD/PXDF).

The reporting template provided in [Annex D](#) proposes additional potential pollutants and indicators for inclusion in the compilation. Not all of the pollutants and indicators listed in [Table D.1](#) are relevant to every fire site, and others not mentioned in the table can apply.

This document does not include direct acute toxicity issues on humans, which are covered by other standards, such as ISO 13344 and ISO 13571.

## 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 5667-1, *Water quality — Sampling — Part 1: Guidance on the design of sampling programmes and sampling techniques*

ISO 5667-20, *Water quality — Sampling — Part 20: Guidance on the use of sampling data for decision making — Compliance with thresholds and classification systems*

ISO 10381-1, *Soil quality — Sampling — Part 1: Guidance on the design of sampling programmes*

ISO 11771, *Air quality — Determination of time-averaged mass emissions and emission factors — General approach*

ISO 13943, *Fire safety — Vocabulary*

ISO 14050, *Environmental management — Vocabulary*

ISO 26367-1:2011, *Guidelines for assessing the adverse environmental impact of fire effluents — Part 1: General*

## 3 Terms and definitions

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

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

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

### 3.1

#### **acute**

sharp or severe in effect, generally used in reference to human health effects

### 3.2

#### **chronic**

continuing over a long time period or recurring at low levels frequently, generally used in reference to human health effects

### 3.3

#### **congener**

<chemistry> related chemicals

EXAMPLE A derivative or an element in the same group of the periodic table.

### 3.4

#### **dioxin**

family of halogenated organic compounds, the most common consisting of polychlorinated dibenzofurans (PCDF) and polychlorinated dibenzodioxins (PCDD), although brominated dioxins and furans are also important

Note 1 to entry: The term polyhalogenated dioxin and furan (PXDD/PXDF) includes any halogen.

Note 2 to entry: Dioxins are among the most toxic substances known to man<sup>[6]</sup>.



**3.5****halogenated acid****HX**

molecule consisting of a positively charged hydrogen atom ionically bonded to a negatively charged halogen atom

Note 1 to entry: Includes hydrogen fluoride (HF), hydrogen chloride (HCl), and hydrogen bromide (HBr).

**3.6****long-term effect**

impacts occurring after a fire, over a period of years

**3.7****perfluorinated compound****PFC**

organofluorine compound containing only carbon-fluorine bonds, carbon-carbon bonds, and other heteroatom bonds, but not carbon-hydrogen bonds

Note 1 to entry: Perfluorooctane sulfonate (also known as Perfluorooctane sulfonic acid, PFOS) and Perfluorooctanoic acid (PFOA) belong to this group of compounds. PFOS and PFOA were recently included in certain fire-fighting foams, but are now replaced in many cases with other organofluoride compounds.

Note 2 to entry: PFOS and PFOA are both perfluorinated alkyl acids (PFAA) compounds, which is a sub-group to the PFC group. The replacement substances for PFOS and PFOA are included in the broader group of poly and perfluorinated alkylic substances (PFAS).

**3.8****persistent organic pollutant****POP**

chemical substance that persists in the environment, bio-accumulates through the food web, poses a risk of causing adverse effects to human health and the environment, and can be subject to long range transport away from its original source

Note 1 to entry: Substances are classified as POPs according to either The Protocol to the regional UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) on POPs, opened for signatures in June 1998 and entered into force on 23 October 2003 or the global Stockholm Convention on POPs, opened for signatures in May 2001 and entered into force on 17 May 2004.

**3.9****pollutant**

chemical species or particulate that is harmful to the environment

Note 1 to entry: This term includes components of fire effluents that cause short-term or long-term impacts on the environment.

**3.10****polycyclic aromatic hydrocarbon****PAH**

hydrocarbon containing two or more aromatic rings

Note 1 to entry: PAHs constitute a complex group. They can be divided into two subclasses, the carcinogenic and the non-carcinogenic. See [C.1](#).

**3.11****short-term effect**

impacts occurring after a fire, over the period of a few minutes to a few days

### **3.12** **toxic equivalent** **TEQ**

weight of the toxicity of the less toxic compounds in a group expressed as fractions of the toxicity of the most toxic compound

Note 1 to entry: Each compound in a TEQ scheme is attributed a specific toxic equivalency factor (TEF). This factor indicates the degree of toxicity compared to the most toxic compound, which is given a reference value of 1. More information is found in Reference [7].

## **4 Use of this document and prerequisites**

### **4.1 Use of this document**

This document is intended to assist individuals and organizations in compiling information about a fire incident and the affected area, which can later be used to assess the adverse environmental impact of emissions from fires. This is best done when comparing data with information collected prior to the fire (baseline data) that includes reference pollutant concentrations. This document is flexible in its application due to the wide range of conditions that can be encountered. The extent of the compilation depends on the intended use of the compilation.

### **4.2 Prerequisites**

In cases where objective, validated information is not available, the user of this methodology should exercise professional judgement in evaluating the fire, establishing data quality objectives, designing sampling programmes, and interpreting the results. For this reason, individuals performing the work should be environmental professionals or should work under the responsible supervision of an environmental professional.

## **5 Identification of data needs**

### **5.1 Data quality objectives**

Prior to initiating a sampling programme, the objectives of the sampling work shall be clearly stated and shall include the following components.

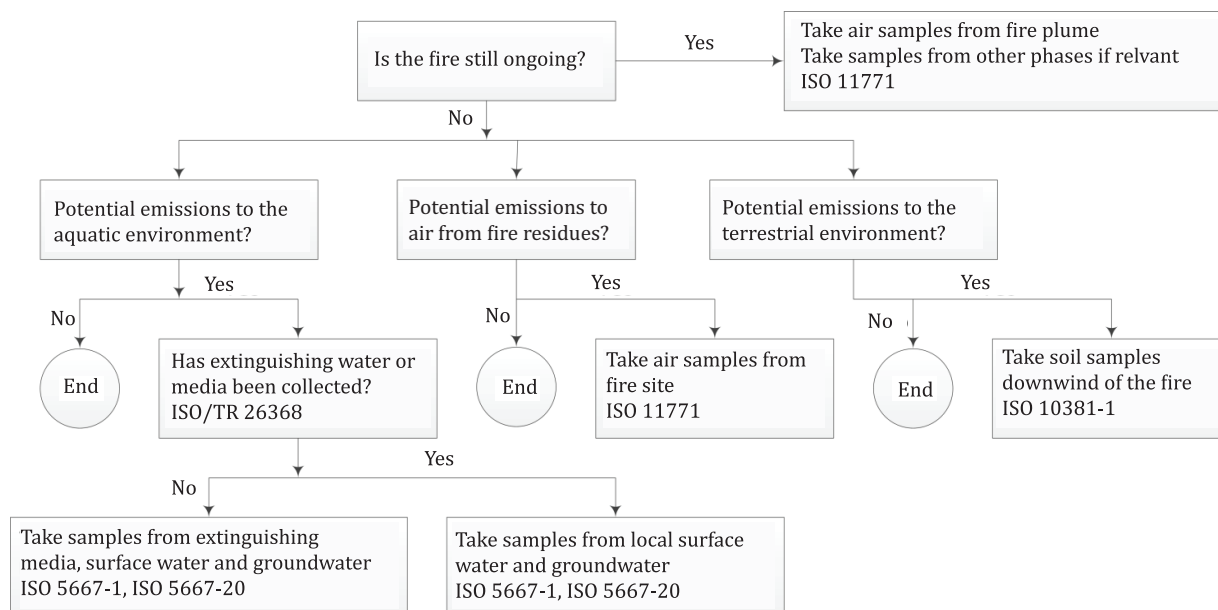
- A concise statement of the problem, including the identification and roles of key decision makers and technical specialists involved in the work.
- The identification of the status of the affected area. Examples include such areas as farm land, drinking water supplies, endangered habitat, and other sensitive biotopes.
- The identification and prioritization of possible decisions that should be made in order to carry out the work. A list of questions that require decisions provides a basis for identifying the decisions. Example questions are: Which environmental phases are affected by fire effluents? What are the remediation requirements? What are the pollutant concentrations? Does the sampling and analysis process have time constraints? Will monitoring be necessary?
- The data requirements that will resolve each of the decisions identified above.
- A definition of boundaries. The boundaries can be spatial, temporal, demographic, regulatory, political, or economic in nature.
- Statements that describe the logical basis for choosing how the sample data will be compared to reference contamination concentrations or other values, which decisions will be made regarding the results of this comparison, and what subsequent actions will be taken based on the decisions.
- Specifications that establish the acceptable degree of uncertainty for each decision.

— An optimized sampling design based on the results of the previous steps.

NOTE See the Bibliography for documents that provide further information about developing effective data quality objectives.

## 5.2 Sampling programme design

**5.2.1** The extent of the fire plume zone, the plume deposition zone, and the transport of pollutants into the environment determine the need for and location of sampling and analysis in the assessment of the environmental impact. The flow chart shown in [Figure 1](#) shall be used, together with the steps listed in [5.1](#) and [Clause 6](#), to determine the type of samples to be collected.



NOTE The International Standards referenced in the boxes in [Figure 1](#) provide useful information about the development of sampling programmes. See [Clause 2](#) or the Bibliography for the full document title.

**Figure 1 — Decision flow chart for environmental sampling with reference to the relevant International Standards**

**5.2.2** The selection and optimization of the sampling programme design is an iterative process that can begin with several sampling programmes that are evaluated against practical, statistical, and cost considerations. The final sampling programme shall be capable of satisfying each of the data quality objectives established in [5.1](#).

NOTE See the Bibliography for documents that provide further information and practical guidance on the selection and optimization of sample designs.

**5.2.3** ISO 5667-1 and ISO 5667-20 shall be consulted for further information about the design of sampling programmes for water, including surface water, groundwater, waste waters, sludges, effluents and bottom deposits.

**5.2.4** ISO 11771 shall be consulted for further information about the design of sampling programmes for air and fire plumes.

**5.2.5** ISO 10381-1 shall be consulted for further information about the design of sampling programmes for soil and related material.

NOTE Emissions to air from residues can be significant after the fire has been extinguished.

**5.2.6** Measurement of the natural level of the pollutants of interest in the vicinity of the fire shall be included in the sampling programme.

**5.2.7** Measurement of natural levels of airborne pollutants shall be conducted upwind of the fire plume zone.

**5.2.8** Measurement of natural levels of soil, standing water, and groundwater pollutants shall be conducted upwind of the plume deposition zone.

**5.2.9** Measurement of natural levels of flowing water pollutants shall be conducted upstream of the plume deposition zone.

NOTE 1 The fire plume zone and fire deposition zone are described in ISO 26367-1:2011, Clause 4.

NOTE 2 Detailed guidance on sampling and analysis techniques is outside the scope of this document and will be the focus of a future document in the ISO 26367 series.

## 6 Selection of pollutants

### 6.1 General

**6.1.1** The environmental professional conducting the work shall select the pollutants to be included in the compilation.

**6.1.2** Pollutants that either typically occur as a result of fire or are particularly harmful to the environment are listed in [6.2](#). The environmental professional conducting the work shall consider whether to include these pollutants in the compilation and shall provide justification for excluding them.

NOTE Certain pollutants/indicators can be judged irrelevant by the environmental professional conducting the compilation, depending on the firefighting tactics used or the specific materials known to be involved in the fire.

**6.1.3** If the environmental professional conducting the work has reason to believe that pollutants having a potentially significant impact on the environment are present at the incident site, other than those listed in [Table 1](#) to [Table 3](#), these pollutants shall be included in the compilation.

NOTE 1 Examples of fire incidents where pollutants other than those listed in [Table 1](#) to [Table 3](#) can be significant include warehouse fires, industrial fires, and vehicle fires, among others.

NOTE 2 Due to the inherent differences between fire incidents, it is not possible to anticipate the presence of every potential pollutant. An extensive list is provided in [Table D.1](#) and can be used as a basis for selection of relevant pollutants. Additional space at the bottom of each category in [Table D.1](#) is provided if a pollutant of interest is not on the list; alternatively, the tables can be expanded.

### 6.2 Indicators and pollutants

**6.2.1** Fire effluent 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 shall be included in the compilation or justification for their exclusion shall be given.

**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 (luminescent bacteria)	Surface water

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

**6.2.2** The pollutants listed in [Table 2](#) are associated with short-term adverse effects on the environment and shall be included in the compilation or justification for their exclusion shall be given.

**Table 2 — Pollutants associated with short-term effects**

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

NOTE Additional background information is provided in [B.1](#) on pollutants having short-term effects.

**6.2.3** The pollutants listed in [Table 3](#) are associated with long-term adverse effects on the environment and shall be included in the compilation or justification for their exclusion shall be given.

**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)	Surface water, groundwater, sediment, soil
Polychlorinated biphenyls (PCB)	Surface water, groundwater, sediment, soil
Polychlorinated dibenzodioxins (PCDD)	Air, deposition on surface water and soil, sediment
Polychlorinated dibenzofurans (PCDF)	Air, deposition on surface water and soil, sediment
Polycyclic aromatic hydrocarbons (PAH)	Air, deposition on surface water and soil
Volatile organic compounds (VOC)	Air, surface water, groundwater, sediment, soil

In some cases, other species should be considered, depending on the suspected substances in the fuel. See [B.2](#).

### 6.3 Documentation of procedures

**6.3.1** Each testing procedure used to physically measure concentrations of pollutants in fire effluents shall be identified, including a reference to the relevant standard and the version or year it was updated.

**6.3.2** The natural level of pollutants in the fire incident area shall be established.

**6.3.3** An indication shall be made as to whether the testing procedures are used to measure concentrations from samples or *in situ*.

**6.3.4** The uncertainty of each pollutant concentration shall be indicated, including the natural concentration level, as well as the method by which the uncertainty was determined.

NOTE 1 For information about uncertainty calculations, see ISO 10576-1[45], ISO 21748[47], ISO/IEC Guide 98-1[48], and ISO/IEC Guide 98-3[49].

NOTE 2 Predictive methods can be employed, either as standalone models or based on empirical physical measurements of key pollutants, in cases where it is not feasible to make physical measurements of each pollutant of interest.

NOTE 3 Additional background information is provided in B.3 on comparison models for pollutants.

**6.3.5** If modelling is performed, the modelling method used for each pollutant shall be clearly identified, including a reference to its source and the version or year it was updated.

**6.3.6** The pollutants shall be assembled into a compilation that includes at least the following data for each sample collected or *in situ* measurement location:

- the species or compound of interest;
- the environmental phase (air, surface water, groundwater, sediment, soil) in which the sample is collected or measured;
- the units of measurement or prediction;
- the measured or predicted value;
- the measurement or prediction uncertainty;
- the sampling method used, including reference;
- the physical measurement technique and/or testing procedure used, including reference and indication of sample or *in situ* measurement;
- the predictive model used, including reference;
- the natural concentration of the pollutant;
- the uncertainty of the natural concentration level;
- the reference level or range;
- the reference level uncertainty;
- the reference level source citation.

## 7 Reporting

### 7.1 Intent of the report

The compilation of environmentally significant emissions from fires shall include all components required by [Clause 6](#). The general reporting scheme described in [7.2](#) to [7.6](#) shall be employed to the

degree that it applies to the intent and objectives of the work. The intended use of the report shall be stated clearly. Some general examples are listed in [Table 4](#), although other uses can exist.

**NOTE** The exact content of a report containing a compilation of emissions that have a potential impact on the environment depends on the intended use of the report. An example reporting format is provided in [Annex D](#) that is designed with the flexibility to be useful for a variety of applications.

**Table 4 — Examples of intended uses of report**

Intent	Comments
Risk assessment	Establishes the potential for adverse impact on the environment prior to a fire incident. Only specific pollutants of interest to the risk assessment need be included.
Environmental Impact Report (EIR) or Environmental Impact Statement (EIS)	Typically a required step in changing land use or ownership in the USA. The contents of the report will depend upon the reporting requirements of the authority to which an EIR/EIS is submitted.
Damage assessment	Investigation of environmental damage during or (normally) after a fire incident
Forensic investigation	Assessment of environmental damage as part of a forensic investigation
Life cycle assessment inventory	Collection of pollutant data from a fire incident for future modelling of environmental impact

## 7.2 Scope of the report

The report shall state clearly what it includes in terms of samples from the air, water and soil, which pollutants will be characterized, the cut-off concentrations for critical pollutants, and the uses for which the data is suitable. A diagram of the scene that indicates the physical boundaries of the contamination shall be included in the report. The viability of the sampling method, and thus also the statistical quality of the data collected shall be stated.

The environmental professional conducting the work shall use his or her expertise to balance the sometimes conflicting issues of providing a comprehensive assessment, acceptable uncertainty of the results, and meeting time constraints when establishing the level of detail and pollutants to include.

**NOTE 1** [D.2.2](#) can be used for establishing the boundaries of the fire impact, the limits of the investigation, and for planning the sampling methodology that will result in data of the desired quality.

## 7.3 Description of incident

**7.3.1** The report shall include a description of the fire incident and the potential exposure pathways to people and the environment with reference to those identified in ISO 26367-1.

**7.3.2** Knowledge of critical events in the progression of the fire incident, weather conditions, emergency response tactics used, possible fuels, and the people present at the incident (both responders and victims) shall be recorded.

**7.3.3** A diagram of the sampling scheme, including a north arrow and approximate scale, as well as the location, number, type, and timing of air, water, and/or soil samples shall be included in the report. The diagram shall provide enough detail to enable reproducibility of the sample collection process.

**NOTE 1** The sampling scheme diagram can be combined with the boundary diagram described in [D.2.2](#).

**NOTE 2** [D.2.3](#) is devoted to the description of the incident.



## 7.4 Characterization of contamination levels

**7.4.1** The requirements given in [Clause 5](#) shall be followed to characterize the levels, phases (e.g. air, water, soil) and physical boundaries of contamination.

**7.4.2** The pollutants shall be reported as absolute concentrations or qualitative estimates. The units used shall be recorded for each pollutant concentration. Unit conversion equations, if applicable, shall be identified in the comments.

**7.4.3** Documentation of background or reference levels of pollutants to establish the natural level of a pollutant shall be complete and traceable.

**7.4.4** Null ( $\emptyset$ ) values shall be used for pollutants with no detectable concentration or concentration below the cut-off value established in the data quality objectives and “NA” shall be used for pollutant concentrations that were not measured or predicted in the compilation.

**NOTE 1** In [D.2.4](#), the sampling, measurement, and/or modelling methods used at each sampling point are keyed to a letter or number that is used in the pollutant table ([Table D.1](#)).

**NOTE 2** The data input to the pollutants table can be used by other parties at a later date for purposes other than that for which it was originally collected. Therefore, it is important to provide as much information as possible about the measurement, sampling, prediction uncertainties, and the methods and assumptions used for every step in the analysis.

## 7.5 Evaluation

**7.5.1** The reason(s) that the sampling scheme, measurement techniques, predictive models, and/or data analysis processes were chosen over other possibilities shall be stated.

**7.5.2** Deviations from referenced sampling and analysis methods and the effects of deviations on the results shall be recorded.

**7.5.3** The procedures used to handle all unusual or outlying data shall be described and unexpected or clearly biased results shall be explained.

**7.5.4** When possible, the resulting data shall be compared with existing data from other sources, such as technical reports or documents generated for the same fire incident, and shall also be compared with the analytical results from similar fire incidents. The data should also be compared to reference baseline data at the same site.

**7.5.5** Any reasons that the results will not support the findings stated in the following clause within acceptable uncertainties shall be explained. If appropriate, recommendations shall be included regarding the need for additional investigation.

**NOTE** [D.2.5](#) is provided for discussion of the characterization process and explanation of any deviations from referenced protocols.

## 7.6 Findings

The findings shall state the environmental impact of fire effluents, given a real or assumed fire incident. The nature of the impact(s), the exposure pathway(s) and the time period for which the condition is expected to exist shall be reported for these adverse impacts:

- acute or chronic adverse impacts to human health (if they are included in the scope of the work);
- short-term effects;



— long-term effects.

In the case of acute effects, the emergency organizations should be contacted immediately.

NOTE 1 [D.2.6](#) is reserved for recording the findings.

It is recommended to make note of any improvements to the process of conducting and reporting the compilation discovered during the work.

## Annex A (informative)

### Examples of levels of pollutants found from fires

#### A.1 Oilfield fires

As the use of oil-based products increases, so does the need to harvest and store these resources. Thus, large tank farms are common in most large cities and the size of the largest tanks increases over time. There are numerous examples of large oil fires and their effect on the environment is potentially huge. [Table A.1](#) contains emissions data from oilfield fires after the Gulf War.

**Table A.1 — Emission data from oil fires**

Fire	Media	Levels of major toxic pollutants quantified
Kuwait oil fires during the Gulf War <sup>[8]</sup>	Smoke gases	Burning wells in Kuwait emitted several thousand tons of gases daily, such as sulfur dioxide (SO <sub>2</sub> ), carbon monoxide (CO), hydrogen sulphide (H <sub>2</sub> S), carbon dioxide (CO <sub>2</sub> ), and the oxides of nitrogen (NO <sub>x</sub> ), as well as particulate matter (PM). These gases contained partially burned hydrocarbons and metals, all of which have potential for affecting human health and vegetation growth. The levels of pollutants such as SO <sub>2</sub> , CO and nitrogen dioxide (NO <sub>2</sub> ) in the ambient air were much lower than the permissible limits defined in the Meteorology and Environmental Protection Agency (MEPA) standards. The pollutants measured during the Kuwaiti Oil Fires were compared with the corresponding values measured in the previous year. The comparison shows that although the concentration of gaseous pollutants were within the MEPA limits, during the period of oil well fires, the concentrations increased persistently which might have been harmful for human health.

#### A.2 Fires in dwellings

Numerous experimental data are available in the literature concerning the emissions from dwelling fires, both from measurements made after real fires and from laboratory tests on model dwellings. Large amounts of organic compounds can be released in house fires.

Examples of emission levels are presented in [Table A.2](#).

Table A.2 — Emission data from fires in dwellings

Fire	Media	Levels of major toxic pollutants quantified
Series of 3 + 3 tests with fully furnished rooms[9][10]	Smoke gases	Inorganic gases: CO <sub>2</sub> ~900 g/kg; hydrogen chloride (HCl) ~1,0 g/kg Volatile organics (VOC): benzene ~1,0 g/kg toluene, phenol, styrene, benzonitrile ~0,1 g/kg each PAH: ~1,0 g/kg, having ~0,02 g/kg BaP-TEQ PCDD/PCDF: 0,0022 µg/kg to 0,033 µg/kg TCDD-TEQ (WHO-1998) (in mass-loss yields)
Toxic chlorinated hydrocarbons (PCB, benzenes, and PCDD/PCDF) and PAH were examined in combustion gas and deposited soot wipe samples from simulated house fires[11].	Smoke gases	Concentrations of these substances were high during the fires, the amounts of PCDD/PCDF in the combustion gas varying from 1,0 ng/m <sup>3</sup> to >7,2 ng/m <sup>3</sup> (I-TEQ) and those of PAH from 6,4 mg/m <sup>3</sup> to 470 mg/m <sup>3</sup> .
NOTE BaP (benzo(a)pyrene)-TEQ and TCDD-TEQ refer to the toxicity weighting scheme for PAH and dioxins. See <a href="#">Annex B</a> and <a href="#">Annex C</a> for more details.		

### A.3 Fires in vehicles/transport

Swedish fire statistics show that automobile fires constitute a significant proportion of the total number of fire incidents, i.e. 15,2 % of all reported fires for 2001. Grayson and Hirschler (2002) have collated similar data for other countries, which shows that the fraction of automobile fires was 10,6 % for the United Kingdom (1985–1999) and 8,6 % for the United States (1985–2000). The number of automobile fires is certainly significant, although the amount of material combusted in each fire is small compared to, for example, building fires.

Further, the emissions from specific transport vehicle fires involving hazardous materials, for example, in bulk tankers, can constitute a far greater potential environmental impact than corresponding fires in vehicles not containing hazardous materials.

Example emissions from a car fire is provided in [Table A.3](#).

**Table A.3 — Emission data from fires in vehicles**

Fire	Media	Levels of major toxic pollutants quantified
Burning of a normal sized European car from 1998 in a laboratory test <sup>[12]</sup>	Smoke gases	Inorganic gases: CO <sub>2</sub> 265 kg, 2 400 g/kg; HCl 1,4 kg, 13 g/kg; SO <sub>2</sub> 0,5 kg, 5,0 g/kg VOC: benzene 322 g, 3,0 g/kg toluene, phenol, styrene, benzonitrile: 0,2 g/kg to 0,7 g/kg PAH (21): 119 g, 1,1 g/kg PCDD/PCDF: 71 µg to 87 µg TCDD-ITEQ, 0,65 µg/kg to 0,80 µg/kg TCDD-ITEQ (in total amounts and mass-loss yield) Metals: zinc (Zn) 3 200 mg/kg, lead (Pb) 820 mg/kg, copper (Cu) 27 mg/kg, antimony (Sb) 15 mg/kg, manganese (Mn) 5,7 mg/kg (in mass-loss yields) PAH (6): 27 µg/l Metals: Zn 8 100 µg/l, Pb 2 300 µg/l, Sb 1 500 µg/l, Cu 760 µg/l, tin (Sn) 120 µg/l (conc. in 105 l collected water)
	Run-off water	

NOTE BaP-TEQ and TCDD-TEQ refer to the toxicity weighting scheme for PAH and dioxins. See [Annex B](#) and [Annex C](#) for more details.

#### A.4 Landfill fires

The emissions produced by burning garbage have been well-characterized by the waste-to-energy sector. Pollutants that are released include: particles, HCl, NO<sub>x</sub>, sulfur oxides (SO<sub>x</sub>), CO, hydrogen cyanide (HCN), H<sub>2</sub>S, mercury (Hg), Pb, PAH, PCB, PCDD/PCDF.

To control these emissions, modern waste to energy plants have been required to install scrubber systems including catalytic reactors, bag-houses and electrostatic precipitators, as well as continuous emission monitoring systems. As a result, emissions from incinerators have declined dramatically. Landfill fires produce the same pollutants produced in incinerators. However, because landfill fires typically occur in an oxygen-deprived environment and at lower burn temperatures, the concentrations of problem pollutants are much higher.

Examples of emission levels are presented in [Table A.4](#).

**Table A.4 — Emission data from landfill fires**

Fire	Media	Levels of major toxic pollutants quantified
Series of 6 tests with simulated deep-set fires in domestic waste. Extinction included in some tests <sup>[13]</sup>	Smoke gases (all 6 tests)	PAH: 0,1 g/kg to 0,6 g/kg PCDD/PCDF: 0,02 µg/kg to 0,4 µg/kg TCDD-ITEQ PCB: 14 µg/kg to 140 µg/kg PCB7, 0,001 µg/kg to 0,06 µg/kg WHO-TEQ Metals: Zn dominating (in mass-loss yields) PAH: ~40 µg/l
	Run-off water (2 tests)	PCDD/PCDF: ~0,005 ng/l TCDD-ITEQ PCB: <0,02 µg/l PCB7 Metals: Zn ~2000 µg/l, Cu ~800 µg/l, Pb ~200 µg/l (All conc. in ~140 l collected water)
	Residues (4 tests × 2 positions)	PCDD/PCDF: 1 ng/kg to 69 ng/kg- dry substance (DS) TCDD-ITEQ PCB: 3,9 µg/kg to 17 µg/kg-DS PCB7, 0,000 7 µg/kg to 0,004 5 µg/kg-DS WHO-TEQ (in mass-loss yields)
Measurements at 3 surface fires at a waste dump <sup>[14]</sup>	Smoke gases	Hg: 0,1 mg/kg to 0,4 mg/kg waste PAH: 0,001 2 g/kg to 0,026 g/kg PCB: 10 µg/kg to 40 µg/kg PCB7 PCDD/PCDF: 0,04 µg/kg to 0,9 µg/kg TCDD-ITEQ (all coarse calculations from plume measurements)
NOTE BaP-TEQ and TCDD-TEQ refer to the toxicity weighting scheme for PAH and dioxins. See <a href="#">Annex B</a> and <a href="#">Annex C</a> for more details.		

## A.5 Fires in storages of used tyres

Bulk storage of tyres is prevalent. Fires in such facilities have the potential to release large amounts of toxic emissions.

[Table A.5](#) contains an example of emissions data for tyre fires.

**Table A.5 — Emission data from fires in storages of used tyres**

Fire	Media	Levels of major toxic pollutants quantified
Series of 4 tests with fires in used tyres. Extinction included in some tests[15][16]	Smoke gases	Inorganic gases: CO <sub>2</sub> 1 900 g/kg to 2 000 g/kg; SO <sub>2</sub> 20 g/kg to 25 g/kg VOC: benzene 1,3 g/kg to 1,9 g/kg, toluene 0,1 g/kg to 0,8 g/kg PAH (16): 1,0 g/kg to 1,9 g/kg PCDD/PCDF: 0,6 ng/kg to 7,2 ng/kg TCDD-ITEQ (not corrected for high background value) Metals: Zn 21 mg/kg to 581 mg/kg, nickel (Ni) 0,5 mg/kg to 18 mg/kg, chromium (Cr) 0,6 mg/kg to 13 mg/kg, Pb 0,2 mg/kg to 8 mg/kg, barium (Ba) 1,3 mg/kg to 6,7 mg/kg (in mass-loss yields)
	Run-off water	PAH (16): 17 µg/l to 440 µg/l PCDD/PCDF: 0,007 ng/l to 0,022 ng/l TCDD-ITEQ Metals: Zn 12 mg/l to 20 mg/l, iron (Fe) ~9 mg/l, cobalt (Co) 0,8 mg/l to 1,0 mg/l, aluminium (Al) ~0,2 mg/l, Mn ~0,4 mg/l (conc. in 20 l to 49 l collected water)
	Residues	PAH: 135 mg/kg to 1 000 mg/kg-DS PCDD/PCDF: 11 ng/kg to 44 ng/kg-DS TCDD-ITEQ Metals: Zn 20 000 mg/kg to 42 000 mg/kg-DS, Fe 1 300 mg/kg to 6 500 mg/kg-DS, Al 550 mg/kg to 1700 mg/kg-DS, Co 240 mg/kg to 580 mg/kg-DS, Cu 61 mg/kg to 200 mg/kg-DS (concentration in collected residues)

## A.6 Fires in storage of electric and electronic (EE) waste

EE waste is collected and stored separately in many waste handling facilities. Emissions from such storage facilities have a potential impact on the environment.

Examples of emissions are given in [Table A.6](#).

Table A.6 — Emission data from fires in storages of EE-waste

Fire	Media	Levels of major toxic pollutants quantified
Series of 4 tests with fires in EE waste. Ex-tinction included in some tests <sup>[15][17]</sup>	Smoke gases	Inorganic gases: CO <sub>2</sub> 1 800 g/kg to 2 000 g/kg; HCl 6 g/kg to 27 g/kg VOC: benzene 4 g/kg to 10 g/kg, styrene 2 g/kg to 14 g/kg PAH (16): 1,7 g/kg to 4,7 g/kg PCDD/PCDF: 1,0 µg/kg to 17 µg/kg TCDD-ITEQ PBDD/PBDF: 28 µg/kg to 703 µg/kg Deka-BDE: 24 µg/kg to 1 200 µg/kg TBBP-A: <1,5 µg/kg to 1 600 µg/kg 2,4,6-Tribromo phenol: <1,5 µg/kg to 3 700 µg/kg Metals: Zn 40 mg/kg to 402 mg/kg, Pb 2 mg/kg to 247 mg/kg, Cu 2 mg/kg to 247 mg/kg, Sb 2 mg/kg to 179 mg/kg, Cr 1 mg/kg to 10 mg/kg (in mass-loss yields)
	Run-off water	PAH (6): 208 µg/l to 434 µg/l PCDD/PCDF: ~0,9 ng/l TCDD-ITEQ decaBDE: 35 ng/l to 470 ng/l TBBP-A: <1 ng/l to 8 ng/l 2,4,6-Tribromo phenol: 7 ng/l Metals: Fe 62 mg/l to 68 mg/l, Pb 11 mg/l to 73 mg/l, Zn 76 mg/l to 120 mg/l, Sb 0,9 mg/l to 4,3 mg/l, Cu 2,4 mg/l to 2,7 mg/l (conc. in 36 l to 83 l collected water)
	Residues	PAH: 38 mg/kg to 160 mg/kg-DS PCDD/PCDF: 15 ng/kg to 2 100 ng/kg-DS TCDD-ITEQ Metals: Zn 1 700 mg/kg to 4 200 mg/kg-DS, Pb 530 mg/kg to 11 000 mg/kg-DS, Cu 14 000 mg/kg to 86 000 mg/kg-DS, Sb 76 mg/kg to 140 mg/kg-DS, Cr 6 mg/kg to 1 000 mg/kg-DS (concentration in collected residues)
NOTE decaBDE is decabromodiphenyl ether and TBBP-A is tetrabromobisphenol A.		

## Annex B (informative)

### Background information on pollutants

#### B.1 Pollutants with short-term effects

Short-term environmental impacts from fires, i.e. impacts occurring after the fire over the period of a few minutes to a few days, pertain mostly to the local environment, within the fire plume zone and water run-off zone.

The three **nitrogen compounds** normally encountered in the atmosphere are nitrous oxide ( $\text{N}_2\text{O}$ ), nitric oxide ( $\text{NO}$ ), and  $\text{NO}_2$ .  $\text{N}_2\text{O}$  is a significant greenhouse gas but is relatively unreactive and does not significantly influence important chemical reactions in the lower atmosphere. Its concentration decreases rapidly with altitude in the stratosphere due to photochemical breakdown, leading to ozone depletion.  $\text{NO}$  and  $\text{NO}_2$  together constitute  $\text{NO}_x$ . These gases are created in the anthropogenic production of energy through the combustion of fossil fuels, combustion in transport and in fires<sup>[18]</sup>.

Atmospheric reactions convert  $\text{NO}_x$  to nitric acid (forming acid rain), inorganic nitrate salts and organic nitrates (contributing to smog).

**Sulfur** in the atmosphere is emitted mainly as  $\text{H}_2\text{S}$ , sulfuric oxide ( $\text{SO}$ ) and  $\text{SO}_2$ .  $\text{H}_2\text{S}$  that gets into the atmosphere is then rapidly converted to  $\text{SO}_2$ .  $\text{SO}$  and  $\text{SO}_2$  together constitute  $\text{SO}_x$ . The main source of  $\text{SO}_x$  in the atmosphere is combustion of fossil fuels containing sulfur (mainly coal), although a small percentage of yearly emissions is produced in fires<sup>[19]</sup>.

Many factors, including temperature, humidity, light intensity, atmospheric transport and surface characteristics of particulate matter can influence the atmospheric chemical reactions of  $\text{SO}_2$ . Whatever the processes involved, much of the  $\text{SO}_2$  in the atmosphere ultimately is oxidized to sulfuric acid ( $\text{H}_2\text{SO}_4$ ) and sulfate salts. The potential for sulphates to induce climate change is high and should be taken into account when considering the environmental impact of  $\text{SO}_2$ <sup>[20]</sup>.

The presence of hydrocarbons and  $\text{NO}_x$  greatly increases the oxidation rate of atmospheric  $\text{SO}_2$ . Indeed these, together with UV-light, constitute the necessary ingredients for the formation of photochemical smog.

**Aerosols** can obscure vision, potentially reducing the ability to escape, a subject addressed by ISO 13571. Particulates can also effect atmospheric smog formation and surface water quality.

**Metals** can have both a severe short-term toxic impact and a long-term impact on the air, surface water, groundwater, sediment, and soil environments and should be identified and, where possible, quantified in order to make an assessment of the environmental impact of a fire<sup>[21]</sup>.

**Halogenated acids** ( $\text{HX}$ ) can enter the environment through combustion processes such as waste incineration<sup>[22][23]</sup> and fires involving halogen-containing fuels.

$\text{HX}$  are also naturally present in the environment. If  $\text{HX}$  are emitted into the atmosphere as gases or aerosols, they can eventually be deposited in surface water or on soil through the scrubbing action of precipitation or agglomeration<sup>[9]</sup>. In the United States, chlorine,  $\text{HCl}$ , and hydrofluoric acid are listed among the 189 Hazardous Air Pollutants in the Clean Air Act Amendments of 1990 (CAAA)<sup>[24]</sup>.

**Volatile organic compounds** ( $\text{VOC}$ ) are a wide-ranging group of chemicals that have a high vapour pressure at normal room temperature. The exact definition varies from country to country and is usually tied to regulations regarding emissions.



## B.2 Pollutants with long-term effects

Long-term environmental impacts from exposure to large fires, i.e. impacts occurring after the fire over a period of years, are experienced largely within the local environment, within the fire deposition zone and along impacted surface and groundwater.

**Metals** are naturally occurring substances that are present in a variety of forms (metal species). As naturally occurring substances, they can always be found at natural (background) concentrations in the different environmental phases. The natural background of a metal in the environment can be defined as the metal fraction that originates from natural geological, biogeochemical and other processes, i.e. not that originating from anthropogenic sources or fires.

Metals differ in their degree of availability to organisms in both aquatic and terrestrial settings. The metal species determines mobility, bioavailability and toxicity of a metal and that speciation depends on the site-specific seasonal and spatial variations existing in a particular water, sediment or soil system.

**Polycyclic aromatic hydrocarbons (PAH)**, which consist of condensed ring aromatic molecules, are produced from the incomplete combustion of organic fuels, e.g. during a fire. These are often found condensed to organic particles<sup>[25]</sup>. The most often cited PAH is benzo(a)pyrene (BaP) as this is the most toxic of the PAH and can be metabolized in the body to a carcinogenic form. The semivolatile property of some PAH makes them highly mobile throughout the environment; the deposition and re-volatilization cycle distributes them between air, soil and water bodies.

[C.1](#) contains more detailed information concerning the members of the PAH family of chemicals and their relative toxicity.

**Polychlorinated dioxins and furans (PCDD/PCDF)** are possibly the most notorious bi-products of the production of pesticides. They are also produced in controlled combustion (e.g. when burning fossil fuels) and during fires. Of the dioxins, the most notable pollutant is 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). This compound is one of the most toxic substances known to man.

[C.2](#) contains more detailed information concerning the members of the PCDD/PCDF family of chemicals and their relative toxicity.

In modern times, **polybrominated dibenzodioxins and furans (PBDD/PBDF)** have also received a significant amount of attention and should be included in any eco-toxicological evaluation of the impact of fire emissions where the fuel contains brominated substances such as brominated flame retardants. There is not as much toxicological information available for PBDD/PBDF (and even less available for dioxins and furans containing both chlorine and bromine atoms) but as a first approximation, it is sufficient to combine the PBDD/PBDF in the same way as described for the PCDD/PCDF<sup>[26]</sup> as described in [C.2](#).

**Polychlorinated biphenyls (PCB)** were first discovered as environmental pollutants in 1866. These compounds are ubiquitous and have been emitted mainly through their use as coolant-insulation fluids in transformers and capacitors, for the impregnation of cotton and asbestos, as plasticizers and as additives to some epoxy paints. Although the use of PCB has been severely restricted, it can still be formed during fires of fuels containing chlorine.

[C.3](#) contains more detailed information concerning the members of the PCB family of chemicals and their relative toxicity.

**Perfluorinated compounds (PFC)**, including Perfluorooctane sulfonate (PFOS) and Perfluorooctanoic acid (PFOA), do not occur naturally in the environment. A source of emission of PFC is the use of certain fire-fighting foam agents such as aqueous film forming foams (AFFF)<sup>[27]</sup>. These compounds are very persistent in the environment and have been found both in the environment and in human blood where it remains for a very long time. PFOS has been shown to give developmental and other adverse effects in laboratory animals<sup>[28]</sup>. Perfluorooctane sulfonic acid (PFOS), associated with AFFF, has been listed by the Stockholm Convention Conference for the Parties in 2009<sup>[29]</sup>.

**Volatile organic compounds (VOC)** include chemicals that are hazardous to the natural environment, such as benzene, formaldehyde, and perchloroethylene. These and other VOC have been found in surface water, groundwater and soil.

## B.3 Comparison models for pollutants

### B.3.1 General

The following models were primarily developed to predict the toxicity of selected species or compounds to humans. In some cases, it is possible to correlate the model output to environmental receptors, particularly when animal testing was used for the model development. When assessing the toxic effect of different groups of compounds, it is necessary to compare against a specified toxic effect or end-point. Proposed models for such comparisons are described below.

### B.3.2 Relative Potency

TCDD is the most toxic species of a class of polyhalogenated aromatic hydrocarbons that are structurally related, have similar toxicity mechanisms and cause the same types of responses. Each chemical compound that fits the criteria for this class is assigned a toxicity equivalence factor (TEF). Birnbaum et al.[30] proposed TEF-values for PCDD, PCDF and dioxin-like PCB. The TEFs for which there is international consensus have been issued by the World Health Organization (WHO)[31].

An extended model has been proposed that compares the dioxin-like activity of additional pollutants[32]. The groups of dioxin-like compounds (DLC) included in the model are PAH, PCDD, PCDF, PCB, polychlorinated naphthalenes (PCN) and polybrominated diphenyl ethers (PBDE). The criteria for including a compound in the model are that the compound a) shares certain structural relationships to PCDD/PCDF; b) binds to the AhR-receptor; c) elicits AhR-mediated biochemical and toxic responses; and d) is persistent and accumulative in the food chain. TEFs have been assigned to compounds from literature data on relative dioxin-like potency (REP). There are consensus values for the most active PCDD, PCDF and PCB, whereas REP-values for the remaining DLC exist but are limited. Investigation of a number of sludges using the model showed that the most important contributing pollutants were PAH > PCN > PCDD/PCDF > PCB > PBDE[32]. It should be stressed that the validity of the model is dependent of the quality of the REP-values used.

[Annex C](#) contains TEFs for chlorinated dioxins, chlorinated furans and PCB relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and for PAH relative to BaP.

**NOTE** Aryl hydrocarbon receptor (AhR) is a cellular protein that is a member of the family of basic-helix-loop-helix transcription factors. AhR is normally inactive but binding to chemicals such as 2,3,7,8-TCDD is leading to changes in gene transcription.

### B.3.3 BaP toxicity model for PAH

There are three generally accepted approaches to modelling the toxicity of PAH that are based on using the toxicity (or carcinogenic potency) of BaP as a reference value: TEF (and a variation of TEF based on carcinogenic potency called potency equivalency factor or PEF), comparative potency, and using BaP as a surrogate[33]. The strengths and weaknesses of each method are discussed briefly here.

**TEF:** This approach requires TEF values for all relevant PAH in the mixture being assessed. TEF values are not available or consistently reported for many PAH. See [C.1](#) for discussion of the calculation of TEF values and see [Table C.1](#) for a list of common PAH and their respective TEFs. High dosage animal studies are typically used to establish TEF values which are then extrapolated to low dosage exposures for humans. Assumptions are made regarding the similarity of test animals to humans, the risks of exposure to PAH being additive, and that the PAH toxicity relative to BaP is consistent for the range of dosages being assessed[33].

**Comparative Potency:** This approach provides an estimate of the toxicity of mixtures without identifying or quantifying the mixture's composition. Risk is expressed as risk per mass of organic content. The major toxic sources that contribute PAH to the environment under study should be characterized to create a reference mixture against which the mixture under study is compared. Difficulties arise in assigning toxic levels to the sources due to their diversity and variability over time[33].

**Using BaP as a Surrogate:** This approach is similar to comparative potency, except that risk is expressed as risk per unit amount of BaP. Assumptions are made that the risk associated with all PAH is proportional to the amount of BaP in the mixture and that the composition of PAH with respect to BaP in the mixture under study is the same as the reference mixture<sup>[33]</sup>.

## B.4 Particle emissions

As a factor in causing injury and death from a fire effluent, very small particles are respirable and can penetrate deep into the lung structure. Inhaled particles themselves can be irritating, reducing the ability to escape from a fire. Aerosols can obscure vision, again potentially reducing the ability to escape, a subject addressed by ISO 13571. Particles can adsorb and/or absorb toxic and irritant gases and vapours. With respirable-sized particles, this can result in transport of the adsorbed gases and vapours deep into the lungs, past the respiratory tract's natural defences. With larger, less respirable or non-respirable particles this adsorption can effectively reduce the concentration of toxic gases and vapours in the fire effluent which might otherwise be inhaled. Further reduction in the concentration of toxic gases and vapours can also occur if they are adsorbed onto particles which subsequently deposit on surfaces.

## B.5 Fire-fighting operations

In many cases, significant amounts of water are used when fighting large scale fires. The containment of the run-off water produced as a direct result of this activity is dealt with in ISO/TR 26368. Should a significant volume of such run-off water be produced from fighting a fire, it is necessary to take water samples and conduct analysis of all long-term pollutants mentioned above to determine the level of contamination of the water. Further, it may be appropriate to conduct analysis for the presence of environmentally significant chemicals that were involved in the fire as fuels.

In certain situations, fire-fighting water contains foaming agents to produce a protective foam layer as part of the fire-fighting tactics. The foaming agent used is water soluble and in some cases also soluble in polar fluids. If an aqueous film forming foam (AFFF) is used as fire suppression media, the run-off water should be analysed for the presence of PFC and concentrations should be catalogued (see [Table D.1](#)).

## Annex C (informative)

### Detailed information on PAH, dioxins and furans, and PCB

#### C.1 Polyaromatic hydrocarbons (PAH)

A list of common PAH together with their TEFs relative to Benzo[a]pyrene (BaP) is given in [Table C.1](#). BaP equivalents ( $E_{\text{BaP}}$ ) represent a weighted sum of all the individual PAH. In this sum, it is assumed that BaP is the most toxic of this group of chemicals and each other member of the group is assigned a factor which describes the toxicity of this species relative to that of BaP. The  $E_{\text{BaP}}$  is then calculated using [Formula \(C.1\)](#):

$$E_{\text{BaP}} = \sum_i a_i (\text{PAH})_i \quad (\text{C.1})$$

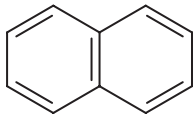
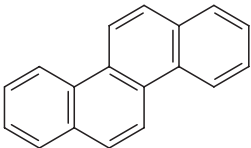
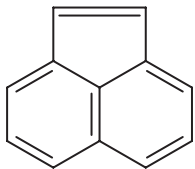
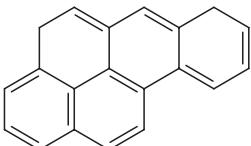
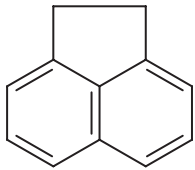
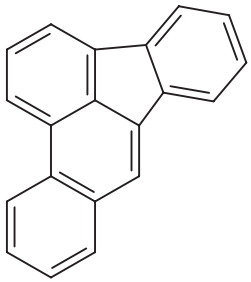
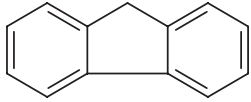
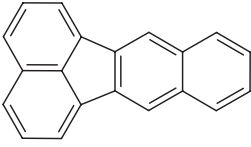
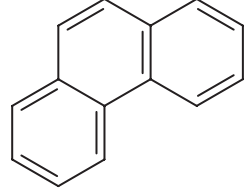
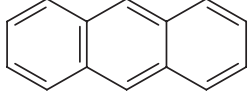
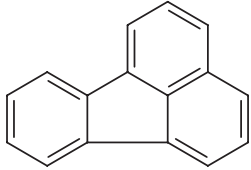
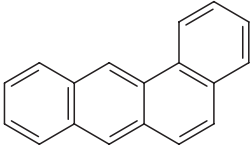
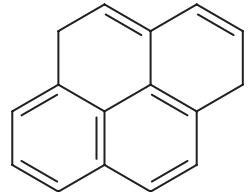
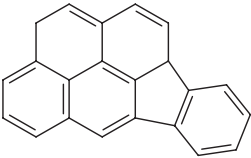
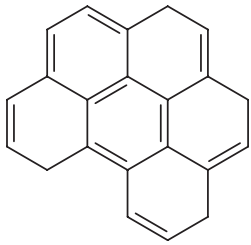
where  $a_i$  is the TEF for the various PAH.

**Table C.1 — List of common PAH and their TEFs according to Reference [34]**

PAH	TEF ( $a_i$ )
Benzo[a] pyrene	1
Benzo[a] anthracene	0,1
Benzo[b] fluoranthene	0,1
Benzo[k] fluoranthene	0,1
Indeno[123-c,d] pyrene	0,1
Anthracene	0,01
Benzo[g,h,i] perylene	0,01
Chrysene	0,01
Acenaphthene	0,001
Acenaphthylene	0,001
Fluoranthene	0,001
Fluorene	0,001
2-methylnaphthalene	0,001
Naphthalene	0,001
Phenanthrene	0,001
Pyrene	0,001

Chemical structures of common PAH are given in [Table C.2](#).

Table C.2 — Chemical structure of common PAH

PAH	Structure	PAH	Structure
Naphthalene		Chrysene	
Acenaphthalene		Benzo(a)pyrene	
Acenaphthylene		Benzo(b)fluoranthene	
Fluorene		Benzo(k)fluoranthene	
Phenanthrene		Anthracene	
Fluoranthene		Benzo(a)anthracene	
Pyrene		Indeno(1,2,3-cd) pyrene	
Benzo(g,h,i)perylene			

## C.2 Dioxins and furans

A list of common chlorinated dioxins and furans with their TEFs relative to TCDD is given in [Table C.3](#). TCDD equivalents ( $E_{TCDD}$ ) represent a weighted sum of both PCDD and PCDF. In this sum, it is assumed that 2,3,7,8-TCDD is the most toxic of this group of chemicals and each other member of the group is assigned a factor which describes the toxicity of the species relative to that of 2,3,7,8-TCDD. The  $E_{TCDD}$  is then calculated using [Formula \(C.2\)](#):

$$E_{TCDD} = \sum_i \left[ a_i (\text{dioxin})_i + b_i (\text{furan})_i \right] \quad (\text{C.2})$$

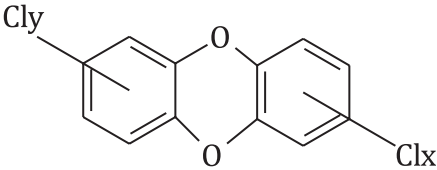
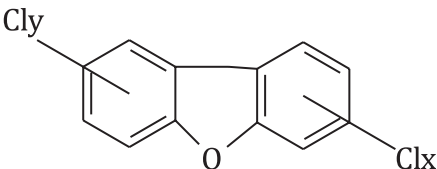
where  $a_i$  and  $b_i$  are coefficients for the various PCDD/PCDF, respectively. There have been several TEF-systems over the years but now there is consensus on the WHO system that also includes TEFs for PCB. [Table C.3](#) contains the most recent WHO-TEFs for dioxins and furans (WHO, 2005) and selected older TEF systems that have been used for some of the data presented in [Annex A](#).

General chemical structures of PCDD and PCDF are given in [Table C.4](#).

**Table C.3 — List of common PCDD and PCDF compounds and their TEFs**[\[31\]](#)

PCDD	TEF (International) <a href="#">[35]</a>	TEF (WHO, 1998) <a href="#">[36]</a>	TEF (WHO, 2005) <a href="#">[31]</a>
2,3,7,8 TCDD	1	1	1
1,2,3,7,8 PeCDD	0,5	1	1
1,2,3,4,7,8 HxCDD	0,1	0,1	0,1
1,2,3,6,7,8 HxCDD	0,1	0,1	0,1
1,2,3,7,8,9 HxCDD	0,1	0,1	0,1
1,2,3,4,6,7,8 HpCDD	0,01	0,01	0,01
Total OCDD	0,001	0,000 1	0,000 3
2,3,7,8 TCDF	0,1	0,1	0,1
1,2,3,7,8 PnCDF	0,05	0,05	0,03
2,3,4,7,8 PnCDF	0,5	0,5	0,3
1,2,3,4,7,8 HxCDF	0,1	0,1	0,1
1,2,3,6,7,8 HxCDF	0,1	0,1	0,1
2,3,4,6,7,8 HxCDF	0,1	0,1	0,1
1,2,3,7,8,9 HxCDF	0,1	0,1	0,1
1,2,3,4,6,7,8 HpCDF	0,01	0,01	0,01
1,2,3,4,7,8,9 HpCDF	0,01	0,01	0,01
Total OCDF	0,001	0,000 1	0,000 3

Table C.4 — Chemical structure of PCDD/F

Substance	Structure
chlorinated dibenzo-p-dioxin (PCDD)	
chlorinated dibenzofuran (PCDF)	

### C.3 Polychlorinated biphenyls (PCB)

PCB includes 209 different congeners of chlorinated biphenyls. In the case of the 12 dioxin-like PCB compounds, it is possible to define TEFs and include PCB compounds in the overall  $E_{TCDD}$  summation defined above. Table C.5 contains a list of the relevant TEFs for dioxin-like PCB compounds. An analysis scheme for PCB often seen in the literature is the ICES 7-PCB scheme that was developed as an indicator scheme for the marine environment. This scheme includes seven congeners; however, only one of these belongs to the group of dioxin-like PCB.

Table C.5 — List of common dioxin-like PCB compounds and their TEFs<sup>[31]</sup>

PCB	TEF (WHO, 1998)	TEF (WHO, 2005)
3,3',4,4'-tetraCB	0,000 1	0,000 1
3,4,4',5-tetraCB	0,000 1	0,000 3
3,3',4,4',5-pentaCB	0,1	0,1
3,3',4,4',5,5'-hexaCB	0,01	0,03
2,3,3',4,4'-pentaCB	0,000 1	0,000 03
2,3,4,4',5-pentaCB	0,000 5	0,000 03
2,3',4,4',5-pentaCB	0,000 1	0,000 03
2',3,4,4',5-pentaCB	0,000 1	0,000 03
2,3,3',4,4',5-hexaCB	0,000 5	0,000 03
2,3,3',4,4',5'-hexaCB	0,000 5	0,000 03
2,3',4,4',5,5'-hexaCB	0,000 01	0,000 03
2,3,3',4,4',5,5'-heptaCB	0,000 1	0,000 03

## Annex D (informative)

### Compilation of environmentally significant emissions from fires

#### D.1 General

The following reporting format for assessing the adverse environmental impact of fire effluents is intended as guidance for reporting a potentially broad range of information collected for a variety of different purposes. It is therefore presented in a general style. However, in order to produce a report having the highest degree of usefulness to others over time, it is recommended that every effort be taken to include as much relevant information as possible. The relevant information should be reliable and have underpinning references supporting it.

#### D.2 Report of adverse environmental impact of fire effluents

Date(s): \_\_\_\_\_ Location(s): \_\_\_\_\_ Fire brigade(s): \_\_\_\_\_

##### D.2.1 Intent of this report:

___Damage assessment	___Risk assessment	___Life cycle assessment
___Forensic investigation	___EIR/EIS	___Other (explain)



**D.2.2 Scope of this report:** (use additional pages as necessary for any section of this report)

Diagram of incident scene (include north arrow, approximate scale, and location, number, type, and timing of air, water, and/or soil samples)

Sampling viability (number of samples, randomization method, sampling scheme/design used)

Data viability (appropriate uses, limitations, uncertainty analyses used)

Comments

**D.2.3 Description of fire incident:**

Weather conditions (wind, temperature, cloud cover, precipitation)

Fire progression narrative (include fire source, first item ignited, fire spread, fuels, firefighting tactics, suppression media, extent and description of burn area, timing)

Potential pollutants

Sensitivity of surroundings (hazardous materials, high fuel loads, vulnerable receptors, what is the worst case?)

Exposure pathways (gas, particulates, ash and debris, deposition, fire-fighting runoff, surface water, groundwater, sediments, soil)

Agencies/organizations at scene (news media coverage, data collected by others: fire measurements, photos, video, forensic data, pollutant samples)

#### D.2.4 Characterization:

Fill in all fields of data in the [Table D.1](#) that are appropriate for the incident under investigation using one table for each sample collected. Enter null (Ø) values for pollutants with no detectable concentration and NA for pollutants concentrations that are not measured or predicted in this report.

Provide a list of all sampling/measurement methods and models used, key them to their respective column in each data table. See [Table D.1](#).

Sampling/measurement method (use more space if necessary)

Method	Sample	<i>In situ</i>	Reference (include year updated)
A			
B			
C			
D			
E			
F			
G			
H			
I			
J			
K			
L			
M			
N			

Modelling method	
Method	Reference (include per year)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
<u>Comments</u>	

**D.2.5 Evaluation:**

Rationale for sampling scheme and data analysis

Explanation for aberrations in methodology

Explanation for aberrations in results (outlying data)

Comparison of methodology and results with existing reports/incidents

Completeness of results in terms of the intent of this report

**D.2.6 Findings**

Acute or chronic effects (air, surface water, groundwater, sediments, soil)

Short-term effects (air, surface water, groundwater, sediments, soil)

Long-term effects (air, surface water, groundwater, sediments, soil)

Suggestions for improvements to this reporting process

Table D.1 — Table of Pollutants Measurement and/or Prediction Results (see following pages, use one table for each sample)

Sample no.	Sample type:			Sample location (coordinates)					Date/time:			
Pollutant/ indicator	Measure- ment unit	Measured value	Measure- ment uncertainty	Sampling/ measurement method used	Predicted value	Prediction uncertainty	Model used	Natural level	Uncertain- ty of natural level	Reference level	Reference level source	Null value
General pollutants/indicators												
pH-value												
Conductivity												
Acidity/ Alkalinity												
BOD												
COD												
Turbidity												
Ammonia												
Cyanide												
Oxygen												
Nitrogen												
Sulfur												
Phosphate(s)												
VOC												
NOX												
SOX												
Halogens												
Halogenated acids												

Table D.1 (continued)

[illegible]

34

34



Table D.1 (continued)

[illegible]

[illegible]

Table D.1 (continued)

[illegible]

Table D.1 (continued)

Sample no.	Sample type:		Sample location (coordinates)						Date/time:			
Pollutant/ indicator	Measure- ment unit	Measured value	Measure- ment uncertainty	Sampling/ measurement method used	Predicted value	Prediction uncertainty	Model used	Natural level	Uncertain- ty of natural level	Reference level	Reference level source	Null value
1,2,3,4,6,7,8 HpCDF												
1,2,3,4,7,8,9 HpCDF												
Total OCDF												
Brominated dioxins and furans												
2,3,7,8 TBDD												
1,2,3,7,8 PeBDD												
1,2,3,4,7,8 HxBDD												
1,2,3,6,7,8 HxBDD												
1,2,3,7,8,9 HxBDD												
1,2,3,4,6,7,8 HpBDD												
Total OBDD												
2,3,7,8 TBDF												
1,2,3,7,8 PnBDF												
2,3,4,7,8 PnBDF												
1,2,3,4,7,8 HxBDF												
1,2,3,6,7,8 HxBDF												
2,3,4,6,7,8 HxBDF												
1,2,3,7,8,9 HxBDF												
1,2,3,4,6,7,8 HpBDF												

Table D.1 (continued)

Sample no.			Sample type:		Sample location (coordinates)						Date/time:		
Pollutant/ indicator	Measure- ment unit	Measured value	Measure- ment uncertainty	Sampling/ measurement method used	Predicted value	Prediction uncertainty	Model used	Natural level	Uncertain- ty of natural level	Reference level	Reference level source	Null value	
1,2,3,4,7,8,9 HpBDF													
Total OBDF													
Polychlorinated biphenyls													
3,3',4,4'-tetraCB													
3,4,4',5-tetraCB													
3,3',4,4',5-pen- taCB													
3,3',4,4',5,5'-hex- aCB													
2,3,3',4,4'-pen- taCB													
2,3,4,4',5-pen- taCB													
2,3',4,4',5-pen- taCB													
2,3,3',4,4',5-hex- aCB													
2,3,3',4,4',5'-hex- aCB													
2,3',4,4',5,5'-hex- aCB													
2,3,3',4,4',5,5'-hep- taCB													
Perfluorinated compounds													

Table D.1 (continued)

Sample no.	Pollutant/ indicator	Sample type:		Sample location (coordinates)					Date/time:			Reference level source	Null value
		Measure- ment unit	Measured value	Measure- ment uncertainty	Sampling/ measurement method used	Predicted value	Prediction uncertainty	Model used	Natural level	Uncertain- ty of natural level	Reference level		
	Perfluorohex- anoic acid (PFHxA)												
	Perfluorohep- tanoic acid (PFHpA)												
	Perfluorooctano- ic acid (PFOA)												
	Perfluoronona- noic acid (PFNA)												
	Perfluorodeca- noic acid (PFDA)												
	Perfluoroun- decanoic acid (PFUnDA)												
	Perfluorodo- decanoic acid (PFDoDA),												
	Perfluorotri- decanoic acid (PFTrDA)												
	Perfluorotetra- decanoic acid (PFTedA)												
	Perfluorobu- tane-sulfonate (PFBS)												
	Perfluorohex- ane-sulfonate (PFHxS)												
	Perfluorooctane sulfonate (PFOS)												

Table D.1 (continued)

[illegible]

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#### Examples of standard environmental quality assessment procedures

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- [41] ASTM D6233-98(2009), *Standard Guide for Data Assessment for Environmental Waste Management Activities*
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- [43] ISO 5667 family of documents provides information about sampling techniques for collection, handling, and storage of surface water, groundwater, waste waters, bottom sediments and sludge samples.
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