COLLECTIVE EXPERT APPRAISAL: SUMMARY AND CONCLUSIONS

Regarding the "expert appraisal for recommending occupational exposure limits for chemical agents"

Assessment of health effects and methods for the measurement of exposure levels in workplace atmospheres for

chlorine trifluoride (CAS No. 7790-91-2)

This document summarises the work of the Expert Committees on health reference values (HRV Committee) and on expert appraisal for recommending occupational exposure limits for chemical agents (OEL Committee) and the Working groups on health effects and on metrology.

Presentation of the issue

On 12 June 2007, AFSSET, which became ANSES in July 2010, received a formal request from the Directorate General for Labour to conduct the expert appraisal work required for establishing recommendations on measures to be taken in the event of specific exposure profiles such as those with peaks.

A first report from AFSSET issued recommendations on measures to be taken in the event of an 8h-OELV with no short-term exposure limit (STELV) (Afsset, 2009).

A second report published addressed the second part of the issue, i.e. substances with a short-term exposure limit (15min-STELV) but no 8h-OELV (Anses, 2010). Among other things, it recommended studying the 36 French substances under French labour law with a short-term exposure limit with no 8h-OELV to recommend health values taken from the most recent scientific literature.

In this context, ANSES has published this report on chlorine trifluoride.

France currently has an indicative 15-minute exposure limit value of 0.4 $mg.m^{-3}$ for chlorine trifluoride. It was set by the Circular of the Ministry of Labour of 1 December 1983.

Scientific background

The French system for establishing OELVs has three clearly distinct phases:

- Independent scientific expertise (the only phase entrusted to ANSES);
- Proposal by the Ministry of Labour of a draft regulation for the establishment of limit values, which may be binding or indicative;
- Stakeholder consultation during the presentation of the draft regulation to the French Steering Committee on Working Conditions (COCT). The aim of this phase is to discuss

the effectiveness of the limit values and if necessary to determine a possible implementation timetable, depending on any technical and economic feasibility problems.

The organisation of the scientific expertise phase required for the establishment of Occupational Exposure Limits (OELVs) was entrusted to AFSSET in the framework of the 2005-2009 Occupational Health Plan (PST) and then to ANSES after AFSSET and AFSSA merged in 2010.

The OELs, as proposed by the Committee “Health Reference Values” are concentration levels of pollutants in workplace atmospheres that should not be exceeded over a determined reference period and below which the risk of impaired health is negligible. Although reversible physiological changes are sometimes tolerated, no organic or functional damage of an irreversible or prolonged nature is accepted at this level of exposure for the large majority of workers. These concentration levels are determined by considering that the exposed population (the workers) is one that excludes both children and the elderly.

These concentration levels are determined by the Committee experts based on information available from epidemiological, clinical, animal toxicology studies, etc. Identifying concentrations that are safe for human health generally requires adjustment factors to be applied to the values identified directly by the studies. These factors take into account a number of uncertainties inherent to the extrapolation process conducted as part of an assessment of the health effects of chemicals on humans.

The Committee recommends the use of three types of values:

- 8-hour occupational exposure limit (8h-OEL): this corresponds to the limit of the time-weighted average (TWA) of the concentration of a chemical in the worker's breathing zone over the course of an 8-hour work shift. In the current state of scientific knowledge (toxicology, medicine, epidemiology, etc.), the 8h-OEL is designed to protect workers exposed regularly and for the duration of their working life from the medium- and long-term health effects of the chemical in question;
- Short-term exposure limit (STEL): this corresponds to the limit of the time-weighted average (TWA) of the concentration of a chemical in the worker's breathing zone over a 15-minute reference period during the peak of exposure, irrespective of its duration. It aims to protect workers from adverse health effects (immediate or short-term toxic effects such as irritation phenomena) due to peaks of exposure;
- Ceiling value: this is the limit of the concentration of a chemical in the worker's breathing zone that should not be exceeded at any time during the working period. This value is recommended for substances known to be highly irritating or corrosive or likely to cause serious potentially irreversible effects after a very short period of exposure.

These three types of values are expressed:

- either in $mg.m^{-3}$, i.e. in milligrams of chemical per cubic metre of air and in ppm (parts per million), i.e. in cubic centimetres of chemical per cubic metre of air, for gases and vapours;
- or in $mg.m^{-3}$, only for liquid and solid aerosols;
- or in $f.cm^{-3}$, i.e. in fibres per cubic centimetre for fibrous materials.

The 8h-OELV may be exceeded for short periods during the working day provided that:

- the weighted average of values over the entire working day is not exceeded;
- the value of the short term limit value (STEL), when it exists, is not exceeded.

In addition to the OELs, the Committee assesses the need to assign a "skin" notation, when significant penetration through the skin is possible (ANSES, 2014a). This notation indicates the need to consider the dermal route of exposure in the exposure assessment and, where necessary, to implement appropriate preventive measures (such as wearing protective gloves). Skin penetration of substances is not taken into account when determining the atmospheric limit levels, yet can potentially cause health effects even when the atmospheric levels are respected.

The Committee assesses the need to assign an “noise” notation indicating a risk of hearing impairment in the event of co-exposure to noise and the substance below the recommended OELs, to enable preventionists to implement appropriate measures (collective, individual and/or medical) (ANSES, 2017).

The OEL Committee also assesses the applicable reference methods for the measurement of exposure levels in the workplace. The quality of these methods and their applicability to the measurement of exposure levels for comparison with an OEL are assessed, particularly with regards to their compliance with the performance requirements in the NF-EN 482 Standard and their level of validation.

Organisation of the expert appraisal

ANSES entrusted examination of this request to the Expert Committee on expert appraisal for recommending occupational exposure limits for chemical agents (OEL Committee). The Agency also mandated:

- The working group on health effects to conduct the expert appraisal work on health effects;
- The working group on metrology to assess measurement methods in workplace atmospheres.

Several ANSES employees contributed to the work and were responsible for scientific coordination of the different expert groups.

The methodological and scientific aspects of the work of this group were regularly submitted to the Expert Committee.

The report produced by the working group takes account of observations and additional information provided by the Committee members.

This expert appraisal was therefore conducted by a group of experts with complementary skills. It was carried out in accordance with the French Standard NF X 50-110 “Quality in Expertise Activities”.

Preventing risks of conflicts of interest

ANSES analyses interests declared by the experts before they are appointed and throughout their work in order to prevent potential conflicts of interest in relation to the points addressed in expert appraisals.

The experts’ declarations of interests are made public on ANSES's website (www.anses.fr).

Description of the method

For the assessment of health effects:

A summary report was prepared by the working group on health effects and submitted to the OEL Committee, which commented on it.

The summary report results from bibliographic information taking into account the scientific literature published on this substance through to 2013. The literature search was undertaken based on the document of the NRC (2007), the document written by the ACGIH (2015), and articles found in the Medline, Toxline and HSDB databases.

For assessment of methods for measuring exposure levels in workplace:

A summary report was prepared by the working group on metrology and submitted to the OEL Committee, which added its own comments.

The summary report presents the various protocols for measuring chlorine in workplace atmospheres grouped together based on the methods they use. These methods were then assessed and classified based on the performance requirements set out particularly in the French Standard NF EN 482: "Workplace atmospheres - General requirements for the performance of procedures for the measurement of chemical agents" and the decision-making criteria listed in the methodology report (ANSES, 2014).

A list of the main sources consulted is detailed in the methodology report (ANSES, 2014).

These methods were classified as follows:

- Category 1A: the method has been recognized and validated (all of the performance criteria in the NF-EN 482 Standard are met);
- Category 1B: the method has been partially validated (the essential performance criteria in the NF-EN 482 Standard are met);
- Category 2: the method is indicative (essential criteria for validation are not clear enough);
- Category 3: the method is not recommended (essential criteria for validation are lacking or inappropriate).

A detailed comparative study of the methods in Categories 1A, 1B and 2 was conducted with respect to their various validation data and technical feasibility, in order to recommend the most suitable method(s) for measuring concentrations for comparison with OELs.

The collective expert appraisal work and its conclusions and recommendations were adopted on 14 december 2015 by the OEL Committee (term of office 2014-2017).

This collective expert appraisal work and the summary report were submitted to public consultation from 10/11/2017 to 10/01/2018. The people or organizations who contributed to the public consultation are listed in appendix 3 of the report (only available in French). The comments received were reviewed by the Committee on Health Reference Values (term of office 2017-2020) who finally adopted this version on the 8 march 2018.

Results of the collective expert appraisal on the health effects

Chlorine trifluoride in gas form is colourless and corrosive and has a sweet but suffocating odour. It is pale green in liquid form and white in solid form.

Occupational uses[1]

The following operations can involve chlorine trifluoride and cause workers to be exposed to this substance:

- Production and transport of chlorine trifluoride;
- Use as a fluorinating agent in organic and inorganic chemical synthesis; use in the separation of uranium isotopes;
- Use as a cutting agent for well castings in oil well drilling;
- Use as a rocket fuel oxidiser, and as an igniter and propellant in liquid propellant rockets and engines;
- Use in nuclear fuel processing; use as a pyrolysis inhibitor for fluorocarbon polymers.

Degradation

According to some authors, ClF_3 reacts violently in the presence of water and ice (Sidgwick, (1950) cited in Chemical Book, 2015). This reaction generates, among other things, two toxic substances, hydrofluoric acid (HF) and chlorine dioxide (ClO_2) (Lombardi and Cheng, 1996).

Aubert *et al.*, (1967) indicate that chlorine trifluoride reacts with water in vapour, liquid or solid phase as follows:

$2\ ClF_3 + 2\ H_2O \rightarrow 4\ HF + ClO_2F + ClF$

The formed products can in turn react with H_2O.

According to Dost *et al.,* 1974, ClF_3 is expected to hydrolyse on contact with the moist air of the respiratory tract and generate chloryl fluoride (ClO_2F) and chlorine monofluoride (ClF). ClO_2F rapidly hydrolyses into ClO_2, HF, and ClO^-; the first two ions are predominant. It is reasonable to assume that these are responsible for the toxic effects of ClF_3 (Dost *et al.,* 1974).

An infrared analysis of ClF_3 (7500 ppm) in ambient air (65% relative humidity) indicated that 85% of the gas had degraded within six seconds (MacEwen and Vernot, 1970). The analysis of dilutions of ClF_3 with air (50% humidity) at nominal concentrations of 1000, 2000 and 5000 ppm found evidence of ClF_3 only for a period of 30 seconds.

Toxicokinetics

Other than those of the study by Dost *et al.,* 1970, described below, no data on the toxicokinetics or metabolism of chlorine trifluoride were found in the literature.

[1] *Source: OSHA, 1978*

Dost *et al.,* 1970 studied the tissue distribution of fluoride ions at various times (t = 0, 2, 6, and 24 hours) after exposing Sprague-Dawley rats to 400 ppm ClF_3 for 15 minutes. The significant variability in the concentrations of fluoride ions measured in the tissues of the three control groups limits the interpretation of this study's results. Fluoride ions were evenly distributed in the soft tissues. No increase in fluoride ions was observed in the lungs over time except for a marginal increase two hours following exposure. A non-significant increase in fluoride ions was observed in the spleen of rats examined immediately or two hours after exposure compared to the control groups. The bone concentration of fluorides, which was initially 118 µg F/g tissue, increased to 172 µg F/g tissue 24 hours following exposure.

General toxicity

ClF_3 is a corrosive substance that can cause serious burns on contact with all body tissues.

Toxicity in humans

The available data for humans involve acute toxicity only.

It was reported, without further details, that exposure to 50 ppm ClF_3 for between 30 minutes and two hours was fatal (Deichmann and Gerarde, 1969, cited in NRC, 2007).

According to Teitelbaum, 2001, the pungent odour and irritation associated with ClF_3 are detected at low enough concentrations to enable exposed individuals to escape before suffering severe damage.

Clinical signs such as headaches, abdominal pain and persistent dyspnoea over a two-hour period were observed in a worker exposed to an unknown concentration of ClF_3 for one to two minutes (Longley *et al.*, cited in NRC, 2007).

Toxicity in animals

Acute and subacute toxicity

All of the acute toxicity data extracted from the NRC document on acute exposure guideline levels (AEGLs) (2007) are given in the table below. The studies mentioned in the table are described in the NRC report (2007).

Table 1: experimental data on the acute toxicity of ClF_3 following exposure in animals (according to NRC, 2007)

Species	Concentration (ppm)	Duration of exposure	Effect[a]	Reference
Monkeys	230	1 hour	LC_{50}	MacEwen and Vernot, 1970 (cited in NRC, 2007)
	127	1 hour	No mortality; sneezing, coughing and gasping	

Dogs	21	6 hours[b]	Severe irritation of the eyes and mucous membranes, recovery the next morning except for eye irritation	Horn and Weir, 1955; 1956 (cited in NRC, 2007)
	5.15	6 hours[b]	Irritation, salivation, sneezing, tear production, coughing	
	1.17	6 hours[b]	Nasal discharge after 45 minutes of exposure, watery eyes after 3 hours of exposure	
Rats	800	13-14 minutes	Approximately LC_{50}	Dost *et al.*, 1974 (cited in NRC, 2007)
		10 minutes	No mortality; severe inflammation of the surface of the mucous membranes, skin burns, tear production, glossy hair, corneal ulceration and shallow breathing	
	400	28 minutes	Approximately LC_{50}	
		25 minutes	Similar to 10 minutes of exposure to 800 ppm	
	480	70 minutes	100% mortality	Horn and Weir, 1955 (cited in NRC, 2007)
		40 minutes	ET_{50}[c]	
	299	1 hour	LC_{50}	MacEwen and Vernot, 1970; Vernot *et al.*, 1977 (cited in NRC, 2007)
	200	1 hour	No mortality; clinical signs: tear production, salivation, difficulty breathing and rhinorrhoea; bleeding from the eyes and nostrils	

	96	4.5 hours	80% mortality	Horn and Weir, 1955 (cited in NRC, 2007)
		3.7 hours	ET_{50}[c]	
	21	6 hours[b]	Rhinitis, tear production. Return to normal state the next morning	Horn and Weir, 1955 (cited in NRC, 2007)
	5.15	6 hours[b]	Minor effects observed	
	1.17	6 hours[b]	No effects	
Mice	178	1 hour	LC_{50}	MacEwen and Vernot, 1970; Vernot *et al.*, 1977 (cited in NRC, 2007)
	125	1 hour	No mortality; clinical signs: tear production, salivation, difficulty breathing and rhinitis; bleeding from the eyes and nostrils	

[a] LC_{50} values were obtained 14 days post-exposure (MacEwen and Vernot 1970 cited in NRC, 2007).
[b]Exposures were repeated; the listed signs were observed during the first day.
[c] ET_{50} is defined as effective time to 50% mortality.

Study in monkeys

Rhesus monkeys (four animals of both sexes/group) were exposed to 0, 127, 150, 200, 300 or 400 ppm for one hour (MacEwen and Vernot, 1970). Concentrations were measured thanks to the reaction of ClF_3 or its decomposition products with dimethylamine. The measurements taken indicated stable concentrations of ClF_3 in the inhalation chamber. Observations were made during exposure and for a period of 14 days post-exposure.

The signs observed in the animals included sneezing, coughing and gasping. The animals exposed to lethal concentrations demonstrated paresis, laboured breathing and cyanosis, preceding coma and death. Alveolar and interstitial haemorrhages involving the entire lungs were observed in all the animals that had died. Most of the deaths occurred two to three hours after exposure. The animals showed signs of cyanosis but there was no methemoglobin. The number of animals that died per dose group was 0/4, 2/4, 1/4, 2/4 and 4/4 animals at the respective concentrations of 127, 150, 200, 300 and 400 ppm. The authors estimated the LC_{50} for one hour of exposure at 230 ppm. Lung congestion, haemorrhage and emphysema were observed in the surviving monkeys 14 days post-exposure (MacEwen and Vernot, 1970).

Study in dogs

Two dogs were exposed to 21 ppm ClF_3 for six hours/day for two days (Horn and Weir, 1955). Immediately after the start of exposure, tear production, rhinitis, coughing, rapid breathing and

salivation were observed in these animals. The study was interrupted on the second day due to defective equipment. The animals were exposed to concentrations above 21 ppm. Corneal ulcers and burns around the nose developed. The animals under observation survived for one month.

The same authors exposed two dogs to an average concentration of 5.15 ppm ClF_3 for six hours/day, five days/week for six weeks (Horn and Weir, 1955). The following clinical signs were observed from the first day: salivation, tear production and rhinitis. Coughing and sneezing were also noted. Moreover, the authors reported that at the end of the first exposure period, the animals did not seem to be affected. The animals showed respiratory distress half-way through the study. The dogs died on the 17th day and 26th day respectively. A limitation of this study reported by the authors was the challenge of maintaining a constant concentration in the inhalation chamber. Concentrations ranging from half to twice the average ClF_3 value were recorded.

Studies in rats

Groups of four to ten male Sprague-Dawley rats were exposed to a concentration of 400 ppm for 20, 25, 30, 35 or 40 minutes or a concentration of 800 ppm for 10, 13, 15, 20, 25 or 30 minutes respectively (Dost *et al.*, 1974). Concentrations of ClF_3 in the exposure chamber were evaluated using an infrared device. Exposure caused severe inflammation of all the exposed mucous membranes in addition to tear production. Mortality rates at 400 ppm as a function of exposure time were respectively: 0/8, 0/4, 4/6, 7/8 and 8/8. At 800 ppm, mortality rates as a function of exposure time were: 0/10, 1/8, 10/10, 8/8, 6/6, and 4/4 respectively. The LC_{50} was not determined in this study.. The authors stated that prolonged exposure as well as exposure to high concentrations of ClF_3 induced skin burns in the animals; their hair became brittle and turned yellow. Corneal ulceration was observed following moderate contact with the substance. Furthermore, all of the animals exposed to ClF_3 had shallow breathing. Exposure to 400 ppm for 30 minutes or more and to 800 ppm for 15 minutes or more was fatal. Death occurred within three hours of exposure. Although the authors did not indicate the observation time post-exposure, they stated that the animals surviving four hours after exposure required only routine care.

Groups of 20 rats were continuously exposed to 96 or 480 ppm until all the animals died (Horn and Weir, 1955). Mortality rates were respectively 50% and 80% after 3.7 and 4.5 hours at 96 ppm. Exposure to 480 ppm caused 50% and 100% mortality after 40 and 70 minutes. The authors noted the corrosive effects of the gas on the equipment and reported variations in the measured concentrations ranging from 50% to twice the expected concentration.

Groups of eight male rats were exposed to 200 or 400 ppm ClF_3 for one hour (MacEwen and Vernot, 1970; Vernot *et al.*, 1977). Although the two studies reported the same experiment, they used different strains of rats. MacEwen and Vernot (1970) mentioned the use of Wistar rats while Vernot *et al*. (1977) indicated they used Sprague-Dawley rats. Observations were made during exposure and for 14 days post-exposure. The authors observed tear production, salivation, difficulty breathing and rhinitis. While none of the animals died at 200 ppm, the situation was different at 400 ppm, causing six of the eight animals to die. The LC_{50} calculated by the authors was 299 ppm.

Study in mice

Groups of 15 mice were exposed to concentrations of 125, 150, 175, 200 or 400 ppm for one hour (MacEwen and Vernot, 1970). All the deaths occurred within 36 hours of the end of

exposure (most occurred within two to three hours of the end of exposure). The authors estimated the LC_{50} at 178 ppm. Mortality ratios were 0/15, 2/15, 4/15, 14/15, and 15/15 at the respective concentrations of 125, 150, 175, 200 and 400 ppm. The examination of the survivors on the 14th day showed lung congestion, oedema, haemorrhage and emphysema.

Chronic toxicity

In the study by Horn and Weir cited above, two dogs were exposed to an average concentration of 1.17 ppm for six hours/day, five days/week for six months (Horn and Weir, 1956). During the first part of the study, signs of irritation were noted (rhinorrhoea, tear production, salivation, blinking and coughing). Rhinorrhoea was generally observed around the 45th minute of exposure, while tear production occurred three hours later.

On the 28th day, the dogs coughed up bloody mucoid material; they blinked and had changes in their respiratory rate at the beginning of each exposure period. After more than 60 days, i.e. 42 exposure periods, the dogs developed pneumonia.

Penicillin was administered but one of the animals died on the 115th day (82 exposure periods). The other animal was sacrificed at the end of the experiment. The lung examination showed purulent bronchitis in the animal that died and alveolar haemorrhage, interstitial oedema and irritation in the animal that survived.

In the same study, rats (n=20) were exposed to an average concentration of 1.17 ppm for six hours/day, five days/week for six months (Horn and Weir, 1956). According to the authors, at the beginning of the study, signs of toxicity were less pronounced in the rats than in the dogs. However, after several weeks of exposure, blood-tinged discharge from the nostrils and eyes was occasionally observed. In addition, the animals seemed depressed. Five rats exposed to ClF_3 died during the study (56th, 71st, 147th, 149th and 178th days), one of which died accidentally. The examination of the lungs of the rats that died during the study showed pulmonary oedema and bronchopneumonia. In the surviving rats, the lung examination found pulmonary irritation.

In this study, the authors also reported difficulties in maintaining the concentration (the concentration to which the animals were exposed increased four times over the six-month period).

No data on the genotoxicity, carcinogenicity or reprotoxicity of ClF_3 were identified in the literature.

OEL establishment

The data available in the literature show that ClF_3 is a corrosive substance and a severe irritant to the mucous membranes following exposure by inhalation. Furthermore, it causes burns on contact with the skin and eyes. The lesions induced by ClF_3 can be extremely severe and are partly attributed to the products generated during its hydrolysis (ClF, HF and Cl_2O) (NIOSH, 1978). Therefore, the OEL Committee recommends establishing a ceiling value (CV) in order to protect workers from these effects.

Ceiling value

The study by Horn and Weir (1956) described above had the advantage of being undertaken with the most susceptible species. Despite its limitations (in particular the small sample size and variations in concentrations), it has been selected as the key study.

According to these authors, two dogs exposed to an average concentration of 1.17 ppm for six hours showed no effects other than rhinitis after three hours of exposure. Similarly, rats exposed to the same concentration for a period of six hours did not show any significant effects. The value of 1.17 ppm can therefore be considered a value inducing rhinitis in dogs after three hours of exposure, i.e. a LOAEL.

Despite its limitations, this study is conducted on dogs; analysis of the available literature to consider that it is the most sensitive species. Moreover, its results are supported by a consistent body of data on rats (Table 1). Thus, based on the LOAEL of 1.17 ppm, it is proposed to use the following adjustment factors:

- an adjustment factor of 3 for the transition from the LOAEL to the NOAEL;
- an adjustment factor of 3 to take into account inter-individual variability.

No adjustment factor has been proposed to take into account inter-species variability since in keeping with the methodology of the OEL Committee for irritating and corrosive substances, variability is deemed minor when the most susceptible species is selected. The analysis of the available literature indicates that dogs are the most susceptible species.

i.e. 1.17 ppm / 9 = 0.1 ppm or 0.38 $mg.m^{-3}$ (conversion factor at 20°C and 101 kPa).

This value has been rounded to 0.4 $mg.m^{-3}$. Despite the high level of uncertainty surrounding this value, it should be recommended as a ceiling value given the high toxicity of ClF_3.

According to the Health Council of the Netherlands (Gezondheidsraad), in an analysis undertaken in 2001, it was not possible to recommend an occupational exposure value based on health criteria in light of the available literature. Moreover, according to the AEGL expert committee, emergency values can be established based on data in the literature.

This value is also in line with that recommended by the ACGIH for the past few years and with the values recommended by several agencies and organisations for HF and HCl respectively.

Considering the exposure of the population to fluoride, particularly through food, the CES wanted to evaluate the additional fluorine intake that exposure to ClF_3 could generate according to the recommended value. This assessment shows that the total daily intake remains below the EFSA recommendation.

"Skin" notation

ClF_3 does indeed have a severe irritating effect on the mucous membranes of the respiratory system but nothing suggests it may cause any systemic toxicity by dermal absorption.

Therefore, the skin notation is not justified for this substance.

"Noise" notation

In the absence of scientific data on the ototoxic effect of ClF_3, no "ototoxic" notation has been assigned for this substance.

Conclusion

8h-OEL: not recommended

15min-STEL: not recommended

Ceiling value: In order to protect workers from the corrosive effects of ClF_3, a ceiling value of 0.4 $mg.m^{-3}$, i.e. approximately 0.1 ppm, has been proposed. This value should not be exceeded at any time of day.

"Skin" notation: not assigned

"Noise" notation: not assigned

Results of the collective expert appraisal on measurement methods in workplace atmospheres

Assessment of methods for measuring chlorine trifluoride in workplace atmospheres

Considering the type of OEL recommended by the OEL Committee for chlorine trifluoride, i.e. a ceiling value, the continuous real-time measurement of exposure is the only type of method that can provide reliable monitoring.

Only one method for the continuous measurement of ClF_3 concentrations was identified (see Table 2).

This is a measurement carried out using an electrochemical cell detector, which can be portable or fixed.

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The air to be analysed is drawn in or diffuses into the cell through a diffusion barrier permeable to gas but not to liquid. Gas is adsorbed on a solid-liquid interface. A redox reaction occurs and the generated current is proportional to the amount of gas adsorbed (INERIS, 2009).

Table 2: Summary table of methods for measuring chlorine trifluoride in workplace atmospheres for comparison with a ceiling value

No.	Method	Examples of devices (non-exhaustive list)
1	Portable or fixed detector - electrochemical cell detection	C2300-Range (RKI Japan), GD-K7D2 (RKI Japan), GD-70D (RKI Japan), MST Gas Sensor 9602-7410 (Honeywell), XPS-7CF (Prism Gas Detection Pvt. Ltd.)

The measurement ranges, from 0 to 1 ppm or 0 to 0.6 ppm, with response times under 60 seconds, seem suited to the measurement of the ceiling value proposed by the OEL Committee. However, the data, taken from sales brochures and installation manuals, are very incomplete. In addition, no information is available as to the conditions of the tests for which the

stated values were determined. The information provided by the manufacturers and distributors in the various manuals and brochures therefore does not establish this method's compliance with the NF EN 45544 standard.

For these reasons, this method has been classified in category 3.

For information, another method for measuring concentrations of ClF_3 was identified. It is a delayed-results method undertaken by pumping in a bubbler containing NaOH and analysing with a specific electrode (OSHA Chemical Sampling Information - Chlorine Trifluoride, http://www.osha.gov/dts/chemicalsampling/data/CH_226700.html, consulted on 20/06/2013).

This method is mentioned here for information only since it is not suitable for measuring concentrations of ClF_3 for comparison with the ceiling value recommended by the OEL Committee. Furthermore, its use is not recommended due to the lack of validation data. Therefore, this method was not evaluated.

Conclusion and recommendations

None of the identified methods enables the reliable continuous monitoring of chlorine trifluoride concentrations in workplace atmospheres.

The validation and construction data on real-time detectors based on detection with an electrochemical cell are inadequate to establish whether this method complies with the requirements of the NF EN 45544 standard. For these reasons, this method has been classified in category 3.

Considering the type of OEL to be monitored for chlorine trifluoride, the ceiling value proposed by the OEL Committee requires the continuous monitoring of exposure or concentrations. The method based on isolated sampling with delayed results (active sampling in bubblers followed by analysis with a specific electrode) is not recommended by the OEL Committee for monitoring the ceiling value for chlorine trifluoride.

Conclusions of the collective expert appraisal

Based on the data currently available, the OEL Committee:

- recommends a ceiling value for chlorine trifluoride of 0.4 $mg.m^{-3}$
- does not recommend setting an 8h-OEL for chlorine trifluoride
- does not recommend setting a 15min-STEL for chlorine trifluoride
- does not recommend a "skin" notation
- does not recommend the "noise" notation.

Regarding the evaluation of methods for measuring chlorine trifluoride in workplace atmospheres, the OEL Committee:

- does not recommend any measurement method, since the measurement method identified does not enable the continuous real-time measurement of chlorine trifluoride concentrations to reliably monitor the ceiling value in workplace atmospheres.

- recommends encouraging research on methods able to take continuous real-time measurements of chlorine trifluoride in workplace atmospheres in order to monitor the ceiling value.

References

Afsset. (2009). Recommandations en vue de limiter l'importance et le nombre de pics d'exposition dans une journée de travail (partie 1). (Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail, France). 23 p.

ANSES. (2017). Valeurs limites d'exposition en milieu professionnel – Document de référence. Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail, France. 57 p.

Anses. (2014). Valeurs limites d'exposition en milieu professionnel – Document de référence. Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail, France. 122 p.

ANSES. (2010). Recommendations issued in view of limiting the extent and number of exposure peaks in a working day: case of substances with a 15min-STEL but no 8h-OEL (part 2). (French Agency for Food, Environmental and Occupational Health & Safety, France). 36 pp.

Health effects part

Aubert J., Bougon R., Carles M. CEA (1967) Hydrolyse du trifluorure de chlore, du monofluorure de chlore et du fluorure de chloryle. Etude de la formation du fluorure de perchloryle. (Comissariat à l'Energie Atomique, France) 19p

Chemicalbook. Chlorine trifluoride chemical properties, usage, production. http://www.chemicalbook.com/ChemicalProductProperty_EN_CB7437735.htm. Consulté en mai 2015.

Dost, F.N., D.J. Reed. T.D. Cooper and C.H. Wang. 1970. Fluorine distribution in rats following acute intoxication with nitrogen and halogen fluorides and with sodium fluoride. Toxicol. Appl. Pharmacol. 17:573-584.

Dost, F.N., D.J. Reed. V.N. Smith and C.H. Wang. 1974. Toxic properties of chlorine trifluoride. Toxicol. Appl. Pharmacol. 27:527-536.

Health Council of the Netherlands : Committee on Updating of Occupational Exposure Limits. Chlorine trifluoride. Health-based Reassessment of Administrative Occupational Exposure Limits. The Hague, the Health Council of the Netherlands 2001; 2000/ 15 OSH/019

Horn, H.J. and R.J. Weir. 1955. Inhalation toxicology of chlorine trifluoride. I. Acute and subacute toxicity. A.M.A. Archives Indust. Health 12:515-521.

Horn, H.J. and R.J. Weir. 1956. Inhalation toxicology of chlorine trifluoride. II. Chronic toxicity. A.M.A. Archives Indust. Health 13:340-345.

Lombardi, D.A., et Cheng M.D. 1996. "Modeling Accidental Releases of Chlorine Trifluoride to the Atmosphere," Paper No. 96-WP66B.02, présenté au 89th Annual Meeting of the Air and Waste Management Association, Nashville, Tennessee, June 23-26)

MacEwen, J.D. and E.H. Vernot. 1970. Toxic Hazards Research Unit Annual Technical Report: 1970. AMRL-TR-70-77, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH; National Technical Information Service, Springfield, VA

NIOSH. U.S. National Institute for Occupational Safety and Health. 1978. Occupational Health Guideline for Chlorine Trifluoride. U.S. Department of Labor.

NRC (National Research Council). (2007). Acute Exposure Guideline Levels for Selected Airborne Chemicals, Volume 5. (National Academy Press, USA). 62 p

Teitelbaum, D.T. 2001. The halogens. Pp. 731-825 in: Patty's Toxicology, Vol. 3, E. Bingham et al., eds. New York: John Wiley & Sons, Inc

Vernot, E.H., J.D. MacEwen, C.C. Haun and E.R. Kinkead. 1977. Acute toxicity and skin corrosion data for some organic and inorganic compounds and aqueous solutions. Toxicol. Appl. Pharmacol. 42:417-423.

Metrology part

NF EN 482 : 2012 - Atmosphères des lieux de travail - Exigences générales concernant les performances des modes opératoires de mesurage des agents chimiques

NF EN 45544 : 2000 - Atmosphères des lieux de travail - Appareillage électrique utilisé pour la détection directe des vapeurs et gaz toxiques et le mesurage direct de leur concentration

- Partie 1 : exigences générales et méthodes d'essai
- Partie 2 : exigences de performance pour les appareillages utilisés pour le mesurage des concentrations de l'ordre des valeurs limites
- Partie 3 : exigences de performance pour les appareillages utilisés pour le mesurage des concentrations très supérieures aux valeurs limites
- Partie 4 : guide de sélection, d'installation, d'utilisation et d'entretien

INERIS (2009) RAPPORT D'ÉTUDE N° INERIS-DRA-08-86244-13727B. Ω 22 - Principes et techniques pour la détection des gaz. Formalisation du savoir et des outils dans le domaine des risques majeurs (DRA-76). Paris, 54 pages.
http://www.ineris.fr/centredoc/DRA_76_OMEGA_22_B2_web.pdf, accédé le 20/06/2013

OSHA ; CDC (1978) – Occupational Health Guideline for Chlorine Trifluoride – 4 pages

(http://www.cdc.gov/niosh/docs/81-123/pdfs/0117.pdf, accédé le 20/06/2013)

OSHA Chemical Sampling Information - Chlorine Trifluoride, http://www.osha.gov/dts/chemicalsampling/data/CH_226700.html, accédé le 20/06/2013)