

Collective expert appraisal: summary and conclusions

Regarding the “expert appraisal on recommending occupational exposure limits for chemical agents”

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

cyanogen chloride [CAS n°: 506-77-4]

This document summarises the work of the Expert Committee 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.

In 2010, ANSES published a report that recommended studying the 36 substances in France with a short-term exposure limit but no time-weighted average (TWA) to recommend health values taken from the most recent scientific literature (ANSES, 2010).

France currently has a 15-minute exposure limit value for cyanogen chloride of 0.6 mg.m⁻³ (0.3 ppm). This value was set in a Circular of 13 May 1987 of the Ministry of Labour.

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 on expert appraisal for recommending occupational exposure limits for chemical agents (OEL Committee), 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 OEL 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 OEL Committee assesses the need to assign a "skin" notation, when significant penetration through the skin is possible (Anses, 2014). 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 OEL Committee assesses the need to assign a “ototoxic¹” 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, 2014).

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 OEL 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).

¹ Since the publication of the ANSES report of 2014, the “ototoxic” notation has been replaced by the “noise” notation as the “noise” notation has been adopted by the European Scientific Committee and has been adopted in the French regulation for styrene.

Description of the method

For the assessment of health effects:

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

The summary report was based on bibliographic information taking into account the scientific literature that had been published on this substance up to 2013. The literature search was carried out using the summary report written by the Health Council of the Netherlands (2004), 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 cyanogen chloride 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 11 May 2015 by the OEL Committee.

The collective expert appraisal work and the summary report were submitted to public consultation from 19/01/2017 to 19/03/2017. No comments were received. The OEL Committee adopted this version on 15 May 2017.

Result of the collective expert appraisal on the health effects

Cyanogen chloride can be found in gas or liquid form depending on the ambient conditions. It is colourless, water-soluble and non-flammable; it has a pungent odour².

Occupational uses³

Cyanogen chloride is used in chemical synthesis (as a synthesis intermediate in organic chemistry). It is also used for the cleaning of metals, the production of herbicides (triazine), the production of synthetic rubber and dyes, the refining of ores and the cleaning of optical equipment.

Cyanogen chloride can also be encountered in certain accidental situations:

- cyanogens are general intracellular toxicants used in chemical warfare in conflict situations in the 20th century and in terrorist contexts more recently,
- fire fumes, in particular from plastics.

Toxicokinetics data

Due to its physico-chemical properties, cyanogen chloride is essentially absorbed by inhalation. It is thought to be rapidly absorbed after exposure by inhalation or by the oral or dermal routes (Health Council of the Netherlands, 2004).

Cyanogen chloride quickly reacts with blood and red blood cells to form hydrogen cyanide (HCN). HCN is mainly produced from red blood cells (Aldridge, 1946). There are two steps to this conversion mechanism. First, cyanogen chloride reacts with a compound containing vicinal amino and sulphhydryl groups (glutathione, N-acetylcysteine, haemoglobin, etc.) to form a cyclic compound. Then the reaction with glutathione enables the release of HCN. The released fraction of HCN has not been determined (Aldridge, 1951).

The metabolism of cyanide ions is described in a document published in 2002 by the Health Council of the Netherlands. The cyanide ion is distributed to numerous organs from the blood compartment. At the highest doses (lethal concentrations), it is found in the liver, lungs, kidneys, brain and blood. The primary detoxification pathway is the formation of thiocyanates by a mitochondrial enzyme, rhodanese (or thiosulfate-sulfure-transferase). Cyanide ions are mainly excreted through urine in the form of thiocyanates following high levels of exposure. Other minor routes of excretion include the exhalation of carbon dioxide and hydrogen cyanide (in trace form) (Health Council of the Netherlands, 2002).

In humans, the rate of detoxification for cyanogen chloride is estimated between 0.02 to 0.1 mg.kg⁻¹.min⁻¹. It could be between 0.03 to 0.06 mg.kg⁻¹.min⁻¹ for rabbits and between 0.02 and 0.04 mg.kg⁻¹.min⁻¹ for dogs depending on the injected dose (Moore, 1946 cited by the Health Council of the Netherlands, 2004).

² Source: INERIS toxicological and environmental data sheet for chemical substances, September 2011 and ACGIH document, 2015

³ Sources: INERIS toxicological and environmental data sheet for chemical substances, September 2011; F.RIVIERE et al, *Intoxication cyanhydrique : y penser, médecine et armées*, 2010, 5, 387-396; C. RENAUDEAU, *les agressions chimiques*, Ed Fransel, April 1997

General toxicity

Cyanogen chloride exerts its toxicity through two mechanisms:

- it induces systemic effects similar to those produced by hydrogen cyanide. In cells, cyanide binds to the ferrous ion of mitochondrial cytochrome oxidase, blocking respiratory chain function. At high concentrations, cyanide blocks the functioning of organs that require high oxygenation and are rich in cytochrome oxidase (brain, heart). Cyanide can also bind to several metalloprotein enzymes containing copper, zinc, cobalt or manganese. In cases of chronic poisoning, these enzymes are blocked, resulting in a wide variety of metabolic disorders.
- it causes intense irritation of the eyes, upper respiratory tract and lungs, due to the formation of hydrogen chloride (Anonymous, Journal of the Royal Army Medical Corps, 2002).

Toxicity in humans

Few data are available on the consequences of human exposure to cyanogen chloride. The data reported in the literature are mainly related to its use as a chemical weapon (poison gas) during World War I.

Acute and subacute toxicity

The clinical signs and symptoms described following exposure to cyanogen chloride are a combination of those produced by a powerful lung irritant and by hydrogen cyanide.

Exposure is immediately followed by intense irritation of the nose, throat and eyes, coughing, tightness, and intense lachrymal secretion. Inflammation of the bronchioles, congestion, and pulmonary oedema can also occur. The progression of symptoms depends on the intensity and duration of exposure.

After these first effects, people exposed to low concentrations can experience dizziness, headaches and nausea, which decrease a few minutes or a few hours after the end of exposure. Moderate toxicity is reflected by more serious impairment of the central nervous system (confusion, coma, etc.).

At high concentrations, loss of consciousness is followed by respiratory arrest, cardiac arrest and death (Anonymous, Departments of the Army, Navy, Air Force, and Commandant, Marine Corps, USA 1995; Parish and Bradshaw, 2004).

The data in the literature on the acute toxicity of cyanogen chloride mainly come from secondary sources (the publications could not be found in the scientific literature). This information is summarised in the following table.

Exposure	Observed effects	Reference
0.7 ppm (1.78 mg.m ⁻³), unknown duration of exposure	Concentration unbearable for humans Strong nose and eye irritation in exposed workers forcing them to run away (unknown number of workers)	Michigan Department of Public Health (unpublished data sent to ACGIH)
1 ppm (2.6 mg.m ⁻³) for 10 minutes	The lowest concentration inducing irritation in humans	Health Council of the Netherlands, 2004 (Prentiss, 1934 and Flury, 1931 cited by Hartung, 1994, Greim, 1997) (old studies with little documentation)
2 ppm for 10 minutes	Unbearable for humans	
20 ppm for 1 minute		
48 ppm (125 mg.m ⁻³) for 30 minutes	Death	
159 ppm (410 mg.m ⁻³) for 10 minutes		
120.63 mg.m ⁻³ for 30 minutes	Death	Watson <i>et al.</i> , 2011
399.5 mg.m ⁻³ for 10 minutes		
20 ppm for 1 minute	Lowest unbearable concentration (missing data: number of individuals, tested concentrations)	Flury, 1921
between 50 and 300 mg-min. m ⁻³	Lung irritation with the development of pulmonary oedema	Watson <i>et al.</i> , 2011

Given that most of these data have been taken from old studies, there are uncertainties regarding the reported exposure measurements.

Subchronic and chronic toxicity

There are currently no reliable data on the long-term effects of cyanogen chloride in humans. Only one publication reports a case following daily exposure to this substance (unknown concentration) for eight months. The main effects observed were muscle weakness accompanied by skin irritation, lung congestion, hoarseness, conjunctivitis, oedema of the eyelids and burning urine (Reed, 1920 cited by ACGIH, 2015).

NIOSH (Emergency Response Safety and Health Database, consulted in December 2012) indicates, without giving any references, that workers can experience headaches and eye irritation, feel tired, experience chest discomfort, have palpitations, loss of appetite and nosebleed. Exposure to low doses of cyanide for long periods leads to the same effects: lung and eye irritation, loss of appetite, sensations of nausea, weakness and dizziness.

Toxicity in animals

Acute toxicity

As for humans, the toxicity data for animals mainly come from secondary sources. Moreover, the experimental conditions of certain studies are not sufficiently described.

The lethal effects of acute exposure by inhalation to cyanogen chloride in five species (mice, cats, rabbits, dogs and goats) were studied by Flury and Zernich (1931) cited by the Health Council of the Netherlands (2004). The results of this study show that exposing mice and cats to 300 mg.m⁻³ of cyanogen chloride for 3.5 minutes is lethal. Furthermore, a concentration of 800 mg.m⁻³ for 7.5 minutes or 120 mg.m⁻³ for six hours is lethal for dogs.

The Health Council of the Netherlands reports the results of a study indicating that dogs are more sensitive to cyanogen chloride than rats and mice. When exposed to the same concentration (260 mg.m⁻³ i.e. 100 ppm), dogs die after 20 minutes versus 37 and 60 minutes respectively for rats and mice (Health Council of the Netherlands, 2004).

In its 2014 update, ACGIH reports that acute exposure by inhalation to cyanogen chloride causes severe respiratory tract irritation with haemorrhagic exudate from the bronchi and trachea, as well as pulmonary oedema (ACGIH, 2015).

Daily exposure (0.5 to 2 hours/day) in dogs and pigs to an unknown concentration of cyanogen chloride for two weeks causes vomiting, diarrhoea, irritation of the eyes and respiratory tract, tachycardia, polypnoea, weight loss and also severe pulmonary congestion (Greim, 1997 cited by the Health Council of the Netherlands, 2004). This study is not available in its original format.

Subchronic and chronic toxicity

No data on subchronic and chronic toxicity in animals were identified in the literature.

Carcinogenicity and Genotoxicity

No data were found in the literature.

Reproductive toxicity

No data were found in the literature.

Establishment of OELs

The data available in the literature show that cyanogen chloride, during exposure by inhalation, even at low concentrations, immediately causes very strong and unbearable irritation of the respiratory tract (coughing, throat irritation, dyspnoea), skin and eyes.

This can lead to complications affecting the central nervous system, cardiovascular system and respiratory tract. In some cases, this irritation is accompanied by cyanosis, followed by a remission period. After this period, the consequences are fairly unpredictable; relapse with pulmonary oedema and death are possible, depending on the concentration and duration of exposure.

The specific local irritating effect of cyanogen chloride is observed at concentrations below those causing cellular anoxia.

Since it is an average value over a period of time, a 15-min STEL cannot be recommended for cyanogen chloride. In fact, the toxicological profile, while incomplete, suggests that irreversible i.e. persistent effects with lesional or functional damage may occur following short-term exposure to high doses (peaks). Thus, in accordance with the methodological document on the establishment of limit values for irritants and corrosives, it is relevant to recommend a ceiling value for cyanogen chloride.

Ceiling value

Due to the high acute toxicity of cyanogen chloride, only a ceiling value (an atmospheric concentration never to be exceeded) would protect workers from possible serious or even irreversible effects following short-term exposure to high doses.

However, given the limitations of the data in the literature, no scientifically sound numerical values can be recommended for cyanogen chloride. It should be noted that there is a French indicative Occupational Exposure Limit (OEL) of 0.6 mg.m^{-3} (Circular of 13 May 1987) for which no supporting documents were found. The available data that were examined do not enable the validity of this 0.6 mg.m^{-3} value to be confirmed.

A ceiling value of 0.3 ppm, i.e. 0.6 mg.m^{-3} or 0.75 mg.m^{-3} , has been recommended by several organisations (ACGIH, NIOSH). The MAK Commission (DFG) in 1973 and the Health Council of the Netherlands in 2004 did not propose any value, considering that the available data for this substance were insufficient.

“Skin” notation

In the absence of a conclusion on systemic toxicity, the "skin" notation was not assigned for cyanogen chloride.

“Noise” notation

In the absence of scientific data on the ototoxic effects of cyanogen chloride, the "noise" notation was not assigned for this substance.

Conclusion

8h-OEL: not recommended

15-min STEL: not recommended

Ceiling value: recommended but it is not possible to identify the concentration not to be exceeded based on scientific data

“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 cyanogen chloride in workplace atmospheres

Considering the type of OEL recommended by the OEL Committee for cyanogen chloride, i.e. a ceiling value (CV), continuous measurement of exposure is the only method which enables a reliable control. Since the OEL Committee could not establish a concentration not to be exceeded due to a lack of sufficient scientific data, the measurement methods could not be assessed with regard to a specific concentration, but the performance of the methods was analysed based on the range of concentrations of their scope of validation and the available data.

Five methods for the continuous measurement of concentrations were identified and are listed in Table 1.

Table 1: Summary table of methods for measuring cyanogen chloride in workplace atmospheres for comparison with a ceiling value

No.	Method	Examples of devices (non-exhaustive list)
1	Portable electrochemical cell sensors	- Some examples (for HCN detection in particular): GSE 667 Ex® (KIMESSA), ALTAIR PRO® (MSA), X-am® 5000 and Pac® 7000 (DRAGER), ToxiPro® (HONEYWELL), Ibrid™ MX6 (OLDHAM), ToxiRae II (RAE SYSTEMS), GAXT-Z-DL (BW TECHNOLOGIES) detectors
2	Fixed electrochemical cell sensors	- Example (for HCN detection in particular): iTRANS.2 (OLDHAM)
3	Portable flame photometers	- Example (for the detection of nitrogen products in particular): AP4C (<i>portable chemical contamination control device</i>) (PROENGIN) ⁴⁽¹⁾
4	Portable ion-mobility spectrometry detectors	- Some examples (for the detection of cyanide agents in particular): LCD 3.2E and LCD3.3 (SMITHS DETECTION)
5	Fixed ion-mobility spectrometry analysers	- Example (for the detection of cyanide agents in particular): SABRE CENTURION II (SMITHS DETECTION)

Other methods were also identified. They either take instant measurements or provide delayed results:

- Instant-read detection tube. Air containing cyanogen chloride passes through a colorimetric detection tube. The length of the coloured layer (indicating a reaction has occurred) is proportional to the concentration of cyanogen chloride.
 - one example is the Dräger "Cyanogen chloride 0.25/a" tube with a measurement range from 0.25 ppm to 5 ppm,
- Active sampling in an impregnated filter (NaOH), extraction (NaOH), then analysis by ion chromatography/conductivity detection or direct potentiometry with an ion-selective electrode (ISE) (INRS MétroPol 027: 2004, IFA 6725: 2012, OSHA ID-120: 1988 and NIOSH 7904, issue 2: 1994)

⁴ (1) J-U. MULLOT, A. BOUSQUET, P.BURNAT, L'AP4C : caractéristiques d'un nouvel appareil de détection des toxiques chimiques de guerre et de certains toxiques industriels, médecine et armées, 2010, 38, 5, p459-464

- Active sampling in a tube containing 600/200 mg soda lime – extraction with water – analysis by ion chromatography using an electrochemical sensor (NIOSH 6017: 2003) or by visible absorption spectrophotometry (NIOSH 6010, issue 2: 1994)
- Passive sampling in an ULTRA II medium (SKC no. 590-259: 600 mg soda lime) – extraction with water – analysis by ion chromatography using an electrochemical sensor (OSHA 1015: 2010)

These methods are mentioned here for information only since they are not suitable for measuring cyanogen chloride concentrations for comparison with the ceiling value recommended by the OEL Committee. Nonetheless, they can be used to quickly estimate a concentration (colorimetric tube method) or monitor exposure (using measurement methods with delayed results). These methods have not been assessed.

Conclusion and recommendations

Given the fact that the OEL Committee recommends a ceiling value, continuous measurement of exposure is the only type of method for a reliable control of this type of OEL.

The identified methods are based on electrochemical cell detection, flame photometry detection or ion-mobility spectrometry. None are reliable methods for a continuous control of the concentrations of cyanogen chloride in workplace atmospheres. In fact, the few available validation data relate to the measurement of hydrogen cyanide and are therefore not specific to cyanogen chloride.

Therefore, these continuous measurement methods are classified in category 3.

Methods based on isolated sampling with instant or delayed results are not recommended by the OEL Committee for controlling a ceiling value for cyanogen chloride, but can be used to rapidly estimate a concentration or monitor exposure.

Conclusions of the collective expert appraisal

Based on the currently available data, the OEL Committee:

- does not recommend establishing an 8h-OEL for cyanogen chloride
- does not recommend establishing a 15-min STEL for cyanogen chloride
- recommends a ceiling value for cyanogen chloride but, given the weaknesses of the bibliographic data currently available, no scientifically sound numerical values can be proposed.
- does not recommend the "skin" notation.
- does not recommend the "noise" notation.

Regarding the limit value, the OEL Committee would like to stress that cyanogen chloride is a substance with significant acute toxicity. Thus, while recommending a ceiling value is justified, no relevant data are available in the literature to establish this value. Given the serious effects associated with exposure to this substance, the OEL Committee recommends taking protective measures to reduce exposure as far as possible. It should be noted that there is a French indicative OEL of $0.6 \text{ mg}\cdot\text{m}^{-3}$ (Circular of 13 May 1987) for which no supporting documents were found. The available data that were examined do not enable the validity of this $0.6 \text{ mg}\cdot\text{m}^{-3}$ value to be confirmed.

It recommends encouraging research to be able to establish a limit value based on sound data.

Regarding the assessment of methods for measuring cyanogen chloride in workplaces, the OEL Committee:

- does not recommend any measurement methods, since of the five identified methods, none have been validated or are reliable for continuously measuring concentrations of cyanogen chloride in workplace atmospheres.
- recommends encouraging research to be able to continuously measure cyanogen chloride in workplace atmospheres in order to enable the control of a ceiling value.

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