

# **NVvA Guideline Respiratory Protective Equipment**



**2024**

# NVvA Guideline Respiratory Protective Equipment 2024

Practical information about the selection and use  
of respiratory protection when working with  
hazardous substances

# Colophon

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## Summary

This NVvA Guideline on Respiratory Protective Equipment is the successor to the guideline 'Selection and use of Respiratory Protective Equipment' from 2001. After more than 20 years, a broad-based working group of the NVvA has updated this guideline.

The choice of using respiratory protective equipment is not as easy as it seems. Even before the selection of a respiratory protective device is discussed, possible measures according to the STOP strategy must first be considered. In this globally accepted hierarchical method for improving working conditions, the use of respiratory protective equipment is the last option. See chapter 2.1 for more information on this.

The basis for the proper use of the right respiratory protective equipment is a well-functioning respiratory protection program. This program describes all aspects for the proper use of respiratory protective equipment, such as selection, maintenance, supervision, face-fit testing, storage, and replacement.

There are many standards that relate to respiratory protective equipment. These standards partly concern the correct technical operation of a product. There are also standards that describe the degree of protection. The International Organization for Standardization (ISO) has drawn up new standards in recent years. In these standards, the starting point is no longer the mask, but the work to be carried out with a respiratory protective device. In addition to the work itself (heaviness, duration, temperature, etc.), the shape of the employee's face is also increasingly decisive for the choice of a good respiratory protective device. The ISO standards have not yet been adopted by the European standards organizations (CEN and NEN for the Netherlands). They are therefore not yet formally applicable. They do, however, offer tools to substantiate the choice of a suitable respiratory protective device.

This guideline provides insight into the options and supports the choice of respiratory protective equipment and the design of the respiratory protection program. In this guideline, the working group provides advice on the use of protection factors and the performance of face-fit tests.

Annex A to this Directive contains a form which collects and records all the relevant information to help you make the right choice of respiratory protective equipment.

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## Abbreviations

|                |  |
|----------------|--|
| ACGIH          | American Conference of Governmental Industrial Hygienists  |
| AEGL           | Acute Exposure Guideline Level   |
| APF            | Assigned Protection Factor   |
| BM             | Biological monitoring  |
| CCBA           | Closed-Circuit Breathing Apparatus   |
| CEN            | Comité Européen de Normalisation / European Committee for Standardization  |
| CROW           | Dutch knowledge institute for infrastructure, public space, traffic and transport, and work and safety                               |
| DFG            | Deutsche Forschungsgemeinschaft  |
| DGUV           | Deutsche Gesetzliche Unfallversicherung  |
| DNEL           | Derived No-Effect Level  |
| ECHA           | European Chemicals Agency  |
| ERPGL          | Emergency Response Planning Guideline  |
| HSE            | Health and Safety Executive  |
| IDLH           | Immediately Dangerous to Life or Health  |
| IFA            | Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung   |
| ISO            | International Organization for Standardization   |
| MAK            | Maximale Arbeitsplatzkonzentration   |
| MRPF           | Minimum Required Protection Factor   |
| MUC            | Maximum Use Concentration  |
| NEN            | Royal Netherlands Standardization Institute  |
| NPF            | Nominal Protection Factor  |
| NIOSH          | National Institute for Occupational Safety and Health  |
| NVAB           | Netherlands Society of Occupational Medicine   |
| NVBR           | Dutch Association for Fire Service and Disaster Management   |
| NVvA           | Dutch Occupational Hygiene Society   |
| OARS           | Occupational Alliance for Risk Science   |
| OSHA           | Occupational Safety and Health Administration  |
| PAC            | Protective Action Criteria   |
| PAPR           | Powered Air Purifying Respirators  |
| PME            | Preventive medical examination   |
| PPE            | Personal Protective Equipment  |
| RA&E           | Risk assessment and evaluation   |
| REACH          | Registration, Evaluation, Authorisation and Restriction of Chemicals   |
| RPE            | Respiratory Protection Equipment   |
| RIVM           | Netherlands National Institute for Public Health and the Environment   |
| SAR            | Supplied-Air Respirator  |
| SCBA           | Self-Contained Breathing Apparatus   |
| SIPFE          | Suffocation, Intoxication, Poisoning, Fire, and Explosion  |
| SIR            | Netherlands Foundation for Industrial Cleaning   |
| STOP-principle | <b>S</b> = Substitution; <b>T</b> = Technical measures; <b>O</b> = Organisational measures; <b>P</b> = Personal Protective Equipment |
| SWPF           | Simulated Workplace Protection Factor  |
| TIL            | Total Inward Leakage   |
| TLV            | Threshold Limit Value  |
| TPE            | Targeted Periodic Examination  |
| TNO            | Dutch organization for applied scientific research   |
| WCD            | Working Conditions Decree  |
| WPF            | Workplace Protection Factor  |

# 1 Introduction

## 1.1 Background

In 2001 the Dutch Association for Occupational Hygiene (NVvA) published the guideline 'Selection and use of respiratory protective equipment [1] to provide occupational health and safety professionals with tools to make a good and well-founded choice in the use of personal respiratory protective equipment. The NVvA has taken the initiative to update this widely used document after 20 years. This updated guideline has been developed by a working group of the NVvA that is composed of occupational health and safety professionals with different expertise, backgrounds and working environments. The objective of the working group was to update the 2001 directive based on current knowledge, insights, techniques and regulations.

The wording and language of the guideline is aimed at the occupational health and safety professional who is involved or interested in the selection, use and maintenance of personal respiratory protective equipment. It is not a scientific document, but it is intended for use in practice.

### *STOP strategy*

If it has been established by means of measurements or calculations that employees may be exposed to hazardous substances and it is desirable or necessary that measures be taken, the measures must be taken according to the so-called occupational hygiene strategy. Specifically, for working with hazardous substances, this has been translated into the STOP strategy. Its aim is to achieve safe and healthy working conditions for workers.

#### **S= Substitution**

First, remove the source (cause) of the problem. This includes replacing a harmful substance with a safer alternative (e.g. water-based paints instead of solvent-based paints). Is replacement not possible or not effective enough?

#### **T = Technical measures**

Then apply technical measures, work processes, equipment and materials that prevent or limit the risks. For example, by shielding the source, using a different working method or cleaner technology, or applying (local) extraction and ventilation. Is such an application not possible or not effective enough?

#### **O = Organisational measures**

Organisational measures ensure that fewer people are exposed to a substance for a shorter period. For example, task rotation, the use of pressurized cabins or separate operating or working areas. Are such measures not possible or not effective enough?

#### **P= Personal Protective Equipment**

Only if the above measures do not yield sufficient results, personal protective equipment will be used for employees who are or may be exposed to hazardous substances. Think of a face shield or mask with filter canister or blower filter unit. Employees are not allowed to wear personal protective equipment permanently. Limit the duration to what is strictly necessary.

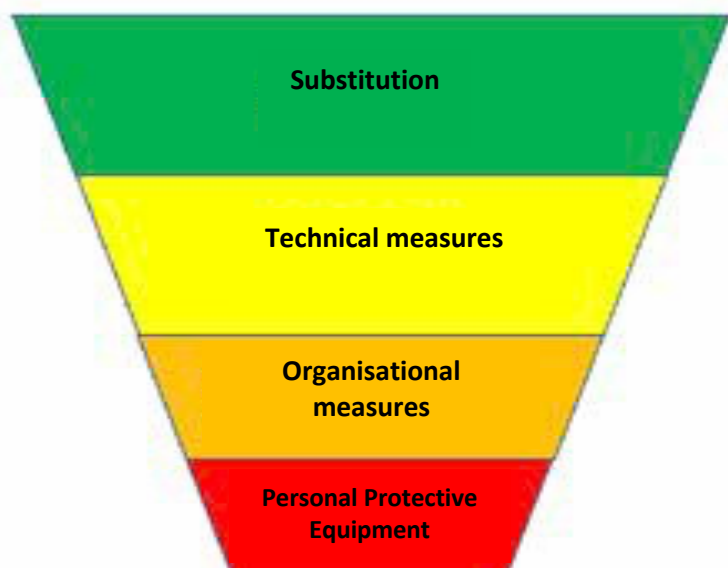


Figure 1-1: STOP strategy

PLEASE NOTE: a distinction is made between 'ordinary' hazardous substances and hazardous substances that are carcinogenic and/or mutagenic and for carcinogenic processes (CMR substances):

- In the case of 'ordinary' hazardous substances: if the higher level is not reasonably achievable, measures may be taken that fall one step lower in the hierarchy. For example, economic aspects may also be considered here.
- For CMR substances: only if the upper level is not technically feasible may a step be taken down the hierarchy. Economic arguments should not be considered.

The reasons for going through these steps in this order is in lieu of the nature of these measures and their contribution to the risk. When descending into the STOP strategy, it is easy to imagine that the chance that something will go wrong when taking the measures increases and thus the risk of exposure also increases.

In addition, descending into the STOP strategy, the required level of knowledge about the protective measures also shifts to the shop floor, which increases the risk of failure. Finally, as the STOP strategy descends, the effectiveness of the measure becomes increasingly dependent on the behaviour of the employee.

The STOP strategy is legally prescribed in the Dutch Working Conditions Decree (hereinafter: WCD). chapter 4, section 1 of the WCD deals with hazardous substances. Article 4.4 of the WCD describes the occupational hygiene strategy. section 2 of chapter 4 of the WCD specifically mentions the requirements for carcinogenic or mutagenic substances and carcinogenic processes. The handling of these substances from the point of view of the occupational hygiene strategy/STOP principle is specifically dealt with in articles 4.17 and 4.18 of the WCD.

The STOP strategy indicates that the wearing of personal protective equipment can only be carried out if the higher-order measures do not provide protection or do not provide sufficient protection.

### *Developments*

Over the past 20 years, there have been many technical innovations at RPE. Manufacturers have made qualitative improvements that have reduced the risk of technical failure, better matched the individual characteristics of the user, and reduced the physical strain. In addition, more and more attention has been paid to the correct selection, good training, correct practical use, cleaning and maintenance of RPE.

The NVvA guideline from 2001 [1] was largely based on the British standard BS 4275 [2]. This 1997 standard was repealed in 2005 and replaced by standard EN 529:2005 [3]. Furthermore, the UK Health and Safety Executive has issued several guidelines to explain the regulations.

Since 2001, there have been developments in several countries and international organizations that have led to new or updated regulations and guidelines. This has been done in Germany, the Netherlands and Europe, among others, by CEN and ISO. Annex B (Legislation and Overview of Respiratory Protection Standards) provides an overview of relevant standards and other documents.

A well-functioning respiratory protection programme (chapter 2) is the cornerstone of this directive. The various components of the programme are further elaborated in the following chapters.

In addition, the guideline devotes considerable time to the discussion of the principles used by the working group with regard to the selection and use of appropriate personal respiratory protective devices. This makes it clear that the selection of suitable personal respiratory protection devices requires a precise and good coordination between regulation and use in practice.

## **1.2 Scope of the guideline**

This document describes types of respiratory protection that meet the definition of 'personal protective equipment' in the Dutch Commodities Act Decree on Personal Protective Equipment 2018 (Warenwetbesluit Persoonlijke Beschermingsmiddelen 2018) and the Dutch Working Conditions Decree (Arbeidsomstandighedenbesluit). Other types of respiratory protection, such as surgical ('medical') face masks and non-medical mouth nose masks, fall outside the scope of this document. In order to give users some information about this type of substance, a brief description is given in section 5.5.

This guideline focuses on personal respiratory protective equipment in work situations, in particular for protection against external substances. This guideline is not made for situations where oxygen needs to be added. Independent respiratory protection is included, provided that it is intended to protect against excessive concentrations of gas or dust. This means that, among other things, the following situations are not fully described in this guideline:

- Deployment of divers
- Repressive activities of the fire brigade
- Emergencies (flights)
- Low oxygen concentrations (less than 18%<sup>1</sup>)
- High oxygen levels (above 21%)

Protection against biological agents (fungi, bacteria, viruses) is briefly discussed, as far as it applies to work situations.

Also in the forms of respiratory protection that do not fall within the scope of this directive, it is possible to use (parts of) the information presented in this guideline. However, in view of the possible risks, additional measures may be necessary, and the working group therefore recommends that an expert be called in or that guidelines drawn up for the relevant respiratory protective equipment and applications be used. See section 7.7 and the Respiratory Protection Manual of the Industrial Cleaning Foundation (SIR) [4].

### 1.3 Reading guide

The guideline is intended for practical use to support occupational hygienists and other occupational health and safety experts with various questions and bottlenecks regarding the selection and use of personal respiratory protective devices. Due to the large amount of background information contained in the directive, the resulting guideline has become hard-to-follow. There is a need for a concise manual. In order to provide for this, the Working Group has added an annex (Annex A) to the Directive in which the various steps are detailed and summarised.

The basis of this directive is a programmatic approach to safe and healthy working with respiratory protective devices. That programme should be put in writing, regularly evaluated and, if necessary, updated. These are the hallmarks of a good respiratory protection program. The programme should focus on the user and not on the means of protection. chapter 2 deals with the respiratory protection programme.

The following chapters are in fact more in-depth on the elements of the respiratory protection programme and give out the options and the aspects important for safe working. Chapter 5 discusses the different protection factors of respiratory protective equipment. Chapter 10 is all about face-fit testing. This is an important part of the proper use of respiratory protective equipment and the respiratory protection programme overall.

Chapter 12 contains the literature used. In the text, [XX] is used as a reference, XX being the serial number in chapter 12.

For the sake of readability, we have abbreviated the term respiratory protective equipment to RPE in this guideline.

We also used 'he' in the text, also for the sake of readability. Where 'he' is written, 'they', 'they', 'them' or 'there' can of course also be read.

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<sup>1</sup> Working Conditions Decree, Article 3.5g:

- there is a risk of asphyxiation if the atmosphere contains less than 18% oxygen by volume.
- risk of fire or explosion if the concentration of oxygen in the atmosphere exceeds 21 % by volume or the concentration of flammable gases or vapours exceeds 10 % by volume of the lower explosion limit.

## 2 Respiratory Protection Program

### 2.1 Structure and content

Many aspects play a role in the correct selection, correct use and proper maintenance of respiratory protective equipment (RPE). Choosing a type of mask with a filter is just one part of that. A respiratory protection programme provides the necessary insight and guidance to make good choices, train employees thoroughly and arrange maintenance properly. The respiratory protection program (RP program) is part of the company's policies and plans for working with hazardous substances. Furthermore, it is part of the STOP strategy and can therefore only be used if measures taken by a higher hierarchy in this strategy do not provide sufficient protection (see chapter 1.1 for an explanation of this).

As part of the programme, tasks, responsibilities and powers should be defined. Periodic evaluations should systematically assess the possibility of reducing the use of RPE through higher-level measures. Evaluations can be part of the risk inventory and evaluation (RA&E) or have their own (fixed) interval.

The standard NEN-EN 529:2005 outlines the requirements for an RP program. More recently, ISO has published four standards (ISO/TC 16975, parts 1 to 4), which currently hold the status of Dutch Pre-standard (NVN). These pre-standards provide further details and new insights compared to NEN-EN 529 regarding the structure and implementation of a respiratory protection program.

Important components of a Respiratory Protection Program (RP program) are:

- Defining tasks and responsibilities;
- Selection of appropriate respiratory protective equipment (RPE) (based on an assessment of tasks, risks, and working conditions);
- Adjusting selected RPE to individual employee characteristics (such as face fit testing);
- Education and instruction;
- Storage;
- Practical use;
- Cleaning and disinfection;
- Maintenance, repair, inspection, and replacement;
- Evaluation;

The following sections provide further explanation of these components.

### 2.2 Tasks and Responsibilities

The implementation of a Respiratory Protection Program (RP program) requires collaboration among multiple stakeholders. It is therefore essential to define the tasks and responsibilities of each party.

The employer holds ultimate responsibility for providing the correct type of respiratory protective equipment (RPE) and ensuring its proper functioning. This means the employer is required to ensure that:

- The RPE is well maintained.
- The RPE is regularly inspected for defects.
- Employees receive education and instruction on the correct use of RPE.
- The appropriate type of RPE and filter is selected.
- Employees receive RPE that is tailored to their individual characteristics.
- The effectiveness of the RPE is regularly tested.
- The Respiratory Protection Program (RP program) is regularly evaluated.

The employer may delegate this task to other qualified individuals within the company. In this guideline, this person is referred to as the line manager.

The following roles are involved in the Respiratory Protection Program (RP program):

- Line Manager – Responsible for overseeing the implementation of the program.
- Program Administrator – Manages and coordinates the program.
- Employees – Must correctly use and maintain their respiratory protective equipment.

- Instructors – Provide training and guidance on proper usage.
- Maintenance Staff – Handle inspection, cleaning, and repairs of the equipment.

The **line manager** is ultimately responsible for the RP program. He can delegate tasks and responsibilities to the program manager.

The **program manager** (usually a safety officer or occupational hygienist) is responsible on behalf of the employer for the design, implementation, and evaluation of the RP program. He has the authority to make the necessary decisions and ensure a successful program. The program manager will draft instructions that include each of the necessary topics of this RP program and is the only authorized person to modify these instructions.

The **program manager** is also responsible for overseeing the proper execution of the RP program. The actual supervision can be delegated to another official with decision-making authority.

**Employees** must use the prescribed ABM correctly and ensure that the equipment is properly stored and replaced. What is considered "correct" is defined in the RP program. Employees have the right to be properly instructed on correct usage, cleaning, storage, and maintenance. They also have the right to individual adjustments to the ABM (for example, a type that fits well to the shape of their face).

**Instructors** are responsible for training the relevant employees, as well as conducting fit tests ('face-fit tests'). They must be well-trained for these tasks.

**Maintenance staff** are responsible for proper maintenance. They must replace ABM if it no longer meets the requirements. They must be well-trained for these tasks.

## 2.3 Selection of the Appropriate Respiratory Protective Equipment

Choosing the right respiratory protective equipment (RPE) is not simple. Many aspects must be assessed to make a well-informed choice:

- Types of RPE;
- Types of filters;
- Protection factors;
- Toxicity of the substances to be protected against;
- Nature of the work (including intensity, duration, freedom of movement);
- Conditions during the work (including heat, cold, drafts, noise);
- Personal factors (including physical condition, medical status, facial shape, facial hair).

Chapters 3 through 9 provide a more detailed discussion of these aspects.

## 2.4 Matching RPE to Individual Characteristics

An important part of an RP program is ensuring that the selected RPE has the right fit for the employee. Facial shape and any facial hair play a key role in this.

Fit tests, commonly referred to as face-fit tests, are conducted to determine whether an RPE fits properly on the face. A face-fit test must be conducted individually by a certified "fit tester." Those performing face-fit tests must demonstrate their competence. This can be achieved if the fit tester has completed training provided by a company that holds the recognized Safety Sign certification.

Only in the asbestos sector is this training legally required. For other sectors, it is recommended. Chapter 10 provides a detailed discussion of the face-fit test.

## 2.5 Education and Instruction

Effective protection is only guaranteed if the respiratory protective equipment (RPE) is used correctly. Education and training play a crucial role in achieving this.

The employer is obligated to provide effective education and instruction to employees regarding the hazards associated with their work. Employees must be informed about the purpose and functioning of personal protective equipment and how to use it properly.

"Effective" means that both oral and written instructions should consider the language and knowledge level of employees. Employees are required to participate in the training.

Additionally, employees must be trained in handling the equipment. Instructors and employees responsible for maintaining and repairing the RPE must also receive training.

### **2.5.1 Education and training of employees**

Educational sessions can be conducted during information meetings for groups of employees. These sessions should address the type of hazardous substances to which employees are exposed, their effects on the human body, and the potential consequences of not wearing RPE or its malfunction during work. It is important to clarify whether the effects are acute or chronic. Additionally, it should be explained that all possible technical measures have been attempted to resolve the issue and why those measures have not yet been fully implemented (the STOP strategy). The characteristics of the RPE being used, including comfort, usability, drawbacks, and functionality, should also be discussed.

Education should not be a one-time event but must be repeated regularly to ensure employees remain motivated to wear and correctly use RPE. By gathering practical feedback, complaints can be identified early, allowing for adjustments or replacements of RPE that employees find uncomfortable.

Special attention must be given to training new employees or those transitioning to a different role within the company. If clear agreements are not made, there is a high risk that such training will be overlooked or incomplete.

Employees working with RPE must be trained in its proper use. The nature and extent of training depend on the specific type of RPE in use and should be tailored accordingly.

During training and instruction, the following aspects should be covered:

- Health effects;
- When to use RPE;
- Where to use RPE;
- Putting on RPE;
- Operating of RPE;
- Importance of correct use;
- Factors leading to leakage;
- Leakage testing;
- Identifying breakthrough and/or leakage;
- No (stubble) beard when using tight-fitting masks;
- What to do in case of malfunction;
- Limitations of the RPE;
- Filter service life;
- RPE maintenance;
- Cleaning procedures;
- Inspection procedures;
- Agreements on storage, reporting malfunctions, etc.

The effectiveness of RPE can only be expected if it is used by well-trained and motivated employees. Additionally, employees should be aware of the importance placed on the issue by company management, which should be demonstrated through:

- Setting a good example;
- Providing high-quality, well-maintained equipment;
- Offering regular training and education when necessary;
- Enforcing proper usage through supervision.

It is recommended to document training content and attendance to ensure future reference in case of uncertainties.

### **2.5.2 Training of Instructors and Maintenance Personnel**

Instructors responsible for employee training must have sufficient knowledge of workplace hazards and their potential health effects. If necessary, they should undergo formal training.

Employees (or external specialists) responsible for fitting and testing RPE must also be trained. They should have a thorough understanding of the function of different types of RPE used in the company, how leaks can occur, and how to identify them. Additionally, they must be aware of all factors affecting wearer comfort.

Maintenance personnel must be technically skilled and understand the construction and function of the RPE in use. They may only use replacement parts recommended by the manufacturer.

Maintenance, inspection, and repairs must be carried out according to the manufacturer's guidelines. Maintenance personnel must be trained to perform their tasks in compliance with these regulations.

## **2.6 Storage**

RPE must be stored in a location where it is not exposed to dust, dirt, chemicals, or mechanical impact. Clean and contaminated (components of) RPE should be stored separately. Storage should follow the user instructions as outlined in the manufacturer's manual.

## **2.7 Practical Use**

RPE is intended for personal use (by one individual) and should not be shared. The benefits of individual use include:

- Hygiene;
- Better fit assurance, reducing leakage risk;
- Greater personal responsibility, leading to more careful handling and timely detection of defects.

Before each use, it is recommended to perform a few simple tests to verify functionality. This should be part of employee education and training.

To ensure correct usage, RPE usage guidelines must be established. The content of these guidelines depends on the specific type of RPE being used. The manufacturer's manual serves as the foundation. Topics that can be included in the guidelines are:

- Inspection procedures: frequency, key points to check;
- Handling RPE: attaching filters, filter type, filter service life, etc.;
- Donning and doffing procedures;
- Identifying leaks/filter breakthrough;
- Application of RPE: suitable work situations, locations, and times, as well as when not to use it;
- Work-rest schedules;
- Procedures for malfunctions or defects;
- Disabling used filters to prevent reuse;
- Disposal of used filters (considering hazardous waste regulations if applicable);
- Hygiene and cleaning instructions.

The service life of filters requires special attention. The manufacturer's recommended usage time must never be exceeded. Once a filter is opened, its usage is limited to a specific period, and the expiration date is no longer valid. If a user detects filter breakthrough (which can occur even within the expected service life), the user must move to a safe area.

## **2.8 Cleaning and Disinfection**

The Working Conditions Decree (Arbeidsomstandighedenbesluit) mandates that RPE must be stored in a designated location according to instructions, cleaned after each use, and inspected before every use (WCD, Article 4.20, section 5, and Article 4.89, section 4). In certain situations, disinfecting RPE may also be necessary.

In addition to hygiene considerations, RPE cleaning is often required due to exposure to hazardous

substances<sup>2</sup>. A distinction is made between two sources of contamination of RPE: internal and external contamination. Internal contamination originates from bodily materials and fluids of the user. External contamination comes from exposure to substances in the workplace.

How well RPE is ultimately cleaned is primarily determined by the parameters from Sinner's Circle [6]. These parameters are:

- Temperature;
- Cleaning/disinfecting agent (chemistry);
- Contact time;
- Cleaning method (mechanical action).

It is important that cleaning and disinfection are carried out in accordance with the instructions of the supplier/manufacture of the RPE.

**Table 3.1: Definitions of Cleaning, Disinfection, and Sterilisation**

|                      | <b>Definitions</b>   |
|----------------------|--|
| <b>Cleaning</b>      | <ul style="list-style-type: none"> <li>• The removal of visible or adhered contamination and invisible organic material to prevent micro-organisms from surviving, multiplying, and spreading.</li> <li>• Cleaning kills 99 - 99.9% of microbes (reduction by a factor of 100 to 1,000; 2 to 3 log reduction).</li> </ul>                                  |
| <b>Disinfection</b>  | <ul style="list-style-type: none"> <li>• The thermal or chemical killing or inactivation of micro-organisms, reducing their number to an acceptable level. • Disinfection kills 99.9 - 99.999% of microbes (reduction by a factor of 1,000 to 100,000; 3 to 5 log reduction).</li> </ul>   |
| <b>Sterilisation</b> | <ul style="list-style-type: none"> <li>• A process that kills or inactivates all micro-organisms on or in an object, such that the probability of live organisms being present per sterilized unit is less than 1 in 10<sup>6</sup>.</li> <li>• Sterilisation kills 99.9999% of microbes (reduction by a factor of 1,000,000; 6 log reduction).</li> </ul> |

When treating RPE, the emphasis should be on cleansing, as this prevents microorganisms from maintaining, multiplying or spreading. In specific circumstances, disinfection may be necessary in addition to cleaning. These specific circumstances are indicated by companies/organisations and concern, for example, work in laboratories where (high) pathogens are handled, preparation of medication in pharmaceutical processes, work in sewers and recovery of human or animal remains.

When cleaning, it must be considered that hazardous substances may be present on or in the RPE. This can pose risks to the person performing the cleaning. This worker must be protected against this by extracting dust (technical measure) or, if this does not provide adequate protection, by wearing adequate personal protection. To prevent contamination and spread, processes and work areas must be clearly defined, with a clear distinction made between contaminated/contaminated and clean/cleaned phases and areas. In Germany, guidelines for a respiratory protection workshop for the fire brigade are described in the standard DIN 14092-7:2012 [7].

## 2.9 Maintenance and repair

Proper maintenance is very important, as a malfunctioning RPE can lead to damage to the user's health. Article 8.3, paragraph 3 of the Working Conditions Decree states that RPE must be maintained, repaired and cleaned and disinfected. For RPE to function properly, the necessary replacements must be made. Maintenance, repair and inspection must be carried out by a trained person (the manufacturer's instructions are leading). When replacing parts, only those parts whose use is indicated by the suppliers in the operating instructions may be used. The supplier or manufacturer's operating instructions provide information on maintenance instructions and replacement intervals.

When using RPE with a supply of breathing air or oxygen, it is advisable to set up a maintenance and repair schedule in close consultation with the supplier. It is also advisable to involve the supplier in carrying out repairs.

<sup>2</sup> Contaminated RPE must **not** be taken home for cleaning or storage, as this is not permitted and strongly discouraged.

Make sure there are enough parts in stock to be able to perform proper maintenance. Regular inspections are part of the maintenance program. This inspection can be combined with cleaning, if the RPE has to be dismantled anyway.

It is important to carry out the inspection based on a checklist so that no parts are skipped. The frequency of inspections depends on the intensity of use, the type of product and the severity of the consequences in the event of failure.

By putting the inspection in writing, it can be checked at a later stage whether defects have been found and whether inspections have been carried out with sufficient frequency. Components of an inspection include:

- Checking connections and connections;
- Checking the functioning of the valves/valves (presence of contamination);
- Checking for damage to the face part, hoses, etc.;
- Control of the warning system (e.g. running out of air supply in the bottles);
- Removal of contaminants;
- Face shield control;
- Control of smoothness, flexibility;
- Check for missing parts;
- Checking fastening straps (breaks, tears, elasticity);
- Checking the filter part (type of filter, fixing, operating time, etc.);
- Checking for the presence of sealing rings for filter canister connection;
- Make it unsuitable for use with gas filters that have expired;
- Checking the purity of the supplied (compressed) air (in the case of RPE with air supply) and replacing filters if necessary.

Hazardous substances may be present on or in the RPE which may pose risks to the person carrying out the inspection. If this is the case, the inspector must be protected from this.

## 2.10 Verification of the effectivity of RPE by biological monitoring

When using RPE as a means of protection against exposure to hazardous substances, it may be desirable to check the effectiveness of the protection. For various reasons, the protection may be insufficient. This can be done, for example, by underestimating the concentration at the workplace, insufficient protection by the RPE, by leakage or by filter breakdown.

For some hazardous substances, it is possible to verify the efficacy-of-the use of RPE by biological monitoring (BM). Biological monitoring is the measurement of a harmful substance or its metabolites in biological material, for example in urine, blood or exhaled air [8]. This makes it possible to estimate the internal exposure and thus the total absorption (via all routes of exposure) of this substance in the body. In fact, it measures the effectiveness of all protective measures. Values that are too high can be caused by excessive exposure through inhalation, but can also be a result of, for example, ingestion through the skin and/or through the mouth. It is necessary to take this into account when interpreting the results of biological monitoring.

Because biological monitoring is carried out with biological material, the results are so-called special personal data and should be treated as such. The company doctor is ultimately responsible for this examination and the interpretation of the data. Therefore, make sure that the company doctor is always involved in the examination.

If biological monitoring is carried out to verify the efficacy of an RP programme, it should be done under representative conditions. If values that are too high are found and it is suspected that this is due to excessive exposure via inhalation, the cause of this exposure will have to be traced.

Possible causes for this could be:

- (Extra) high concentrations in the workplace;
- Leakage of RPE due to poor maintenance;
- Filter breakdown due to overuse of filters;
- Secondary exposure from contaminated clothing and/or gloves;
- Storage of RPE in a contaminated environment;

- Leaking RPE from facial hair;
- Regularly turning off or opening RPE during use (not setting up in time);
- Exposure to hazardous substances during breaks;
- Exposure in the private sphere.

## 2.11 Evaluation

The RP programme should be reviewed regularly, for example annually. It is recommended that a distinction be made between 'policy' and 'implementation' in the evaluation. At the company level, the emphasis will be on the policy: principles, objectives and organisation of the RP programme. The practical implementation of the RP programme is then examined in more detail, for example at department level. This includes periodic inspections at the sites where RPE is used to check whether the use is in accordance with the program. The insights gained at policy and implementation level will be used to adjust the programme and thus improve the effectiveness and efficiency of the deployment of RPE.

### 3 Overview of Respiratory Protective Devices

This chapter provides a concise overview of respiratory protective equipment (RPE) that can be used against exposure to chemical and biological agents. There are two main types of RPE: devices with a fresh air supply (independent respiratory protection) and filtering devices (dependent respiratory protection). The European standard EN 133 [9] provides a classification of types of RPE. The most relevant types are described in this chapter. Appendix B (Legislation and overview of standards for respiratory protection) contains a detailed overview of the standards RPE must comply with.

#### 3.1 Filtering Devices

Filtering devices consist of filter material or are equipped with a filter. This type of device is also referred to as "ambient air-dependent RPE". Through filtration, harmful components are removed from the air, after which the filtered air is inhaled. Figure 4.1 provides a schematic overview of filtering devices. Filtering RPEs are equipped with a particle filter, a gas/vapor filter, or a combination filter. Chapter 4 contains more information about filter types.

There are powered and non-powered filtering devices. With non-powered filtering RPE, the user draws air through the filter. This type may be in the form of a filtering facepiece (also known as a "snout"), half mask, or full-face mask. During inhalation, a negative pressure is created in the RPE relative to the surrounding air. To prevent leakage around the edges, it is important that the mask fits tightly to the face.

Powered filtering RPEs are equipped with a blower unit that blows the filtered air into the RPE. The air can be blown into a face mask, hood/helmet, or a suit. With these systems, inward leakage may occur when, during heavy exertion, the breathing volume per minute exceeds the amount of filtered air supplied per minute. Therefore, with variants that use a full-face mask, a good facial seal is essential. To ensure a proper seal, a face-fit test is required. See chapter 10 for more information on face-fit testing.

If being clean-shaven daily or performing a face-fit test is impractical, then "loose-fitting" RPE can be used instead. See also paragraphs 9.6 and 9.7.

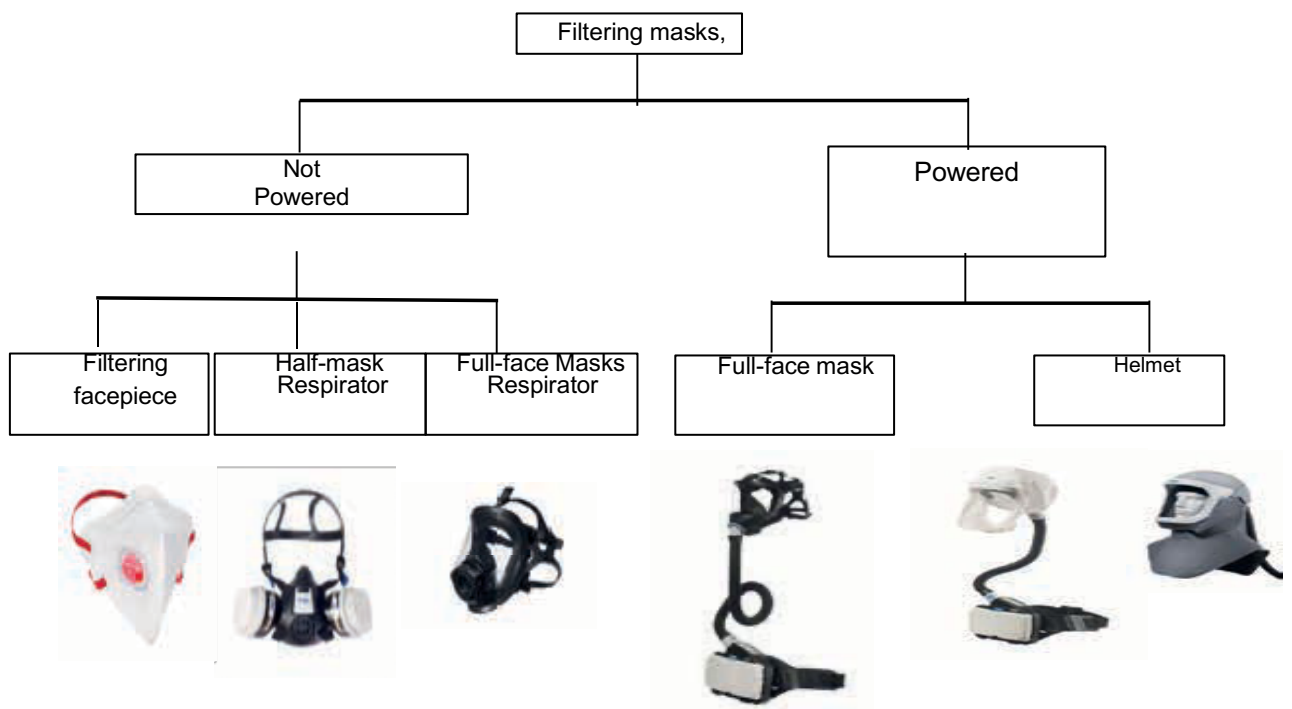
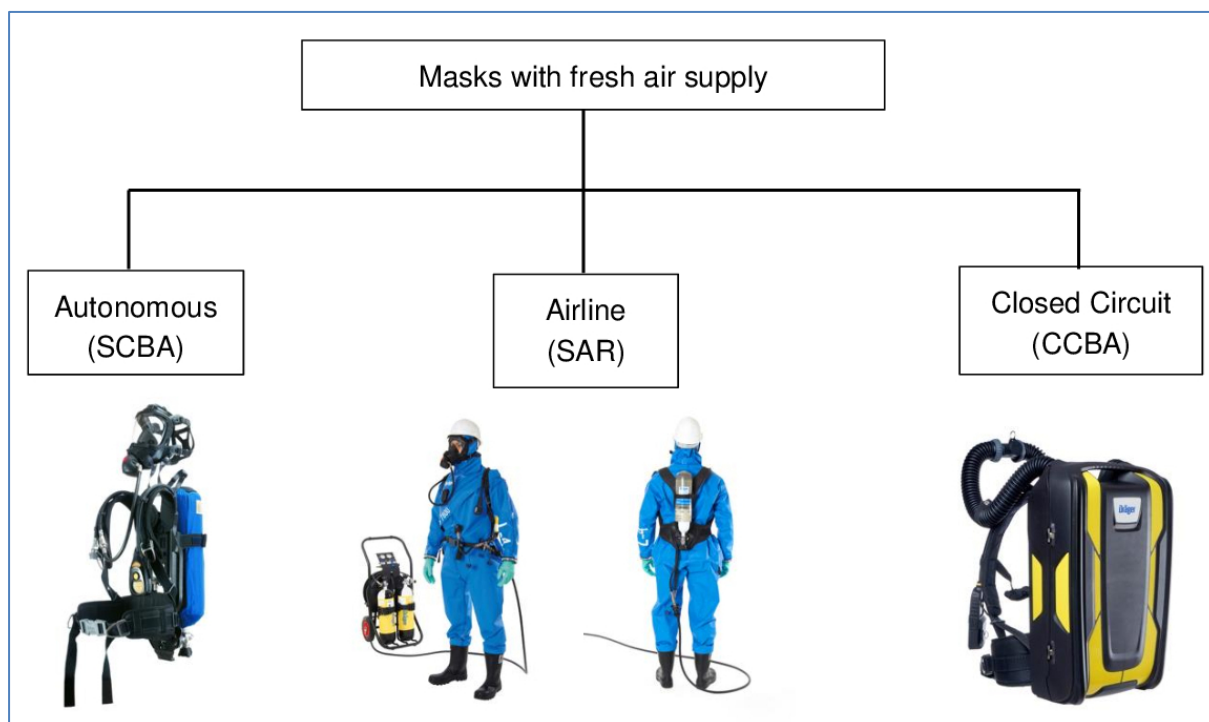


Figure 4.1: Filtering agents

## 3.2 Respiratory protection with fresh air supply (breathing apparatus)

Respiratory protection with a fresh air supply, or breathing apparatus, is not dependent on the ambient air. There are three types of systems to distinguish, see figure 4.2:

- Self-contained breathing apparatus (SCBA): The air is carried in a cylinder on the back.
- Airline system or Supplied-Air Respirator (SAR): The air is supplied from a breathing air system via a long hose. The air can come from a set of gas cylinders, a compressor that draws in ambient air, or a combination of both. Work air or industrial air cannot simply be used. When using a compressor, an extra filter package must be used to remove any contaminants, such as oil mist, from the breathing air.
- These systems exist in mobile form but can also be installed as a fixed piping system for 'breathing air' in a facility (factory). In practice, airline systems are connected to full-face masks, helmets/hoods, or a suit. There may also be a backup breathing air hose and/or a small breathing air cylinder available for evacuation from the workplace.
- Pay attention to the following aspects: maximum hose length, maximum number of couplings, minimum and maximum pressure, and minimum flow rate. There are standards and certification systems for working with compressors. The entire system (compressor, hoses, and hood/helmet) must comply with the European PPE Regulation (included in the Personal Protective Equipment Decree 2018 of the Commodities Act).
- Closed-circuit breathing apparatus (CCBA): In this system, the exhaled air is recirculated after removing carbon dioxide and adding oxygen. This type is used in a limited number of situations in practice, for example in mining and firefighting, and is not further described here.



**Figure 4.2:** Fresh air supply agents

By using compressed air when filling breathing air cylinders, the correct oxygen content is ensured. Compressed air for breathing apparatus must meet the quality requirements as described in NEN-EN 12021 [10]. This standard specifies several quantitative requirements for the composition of breathing air. Additionally, the breathing air must be free from unpleasant odours or tastes, and it must be sufficiently dry (i.e., it should contain very little water vapor). The reason for this is that compressed air cools upon expansion, which can lead to condensation and freezing of water vapor. This could result in blockage of the air supply line. The maximum allowable amount of water vapor depends on the maximum supply pressure of the air.

**Table 4.1:** Composition of breathing air

| Component   | Concentration  |
|---|--|
| Oxygen  | 21 ± 1 %   |
| Carbon dioxide  | < 500 ppm  |
| Carbon monoxide   | < 5 ppm  |
| Oil Mist  | < 0.5 mg/m <sup>3</sup>  |
| Water vapor (measured at atmospheric pressure and 20°C) | Some examples: <ul style="list-style-type: none"><li>• 290 mg/m<sup>3</sup> – at 5 bar supply pressure</li><li>• 160 mg/m<sup>3</sup> – at 10 bar supply pressure</li><li>• 110 mg/m<sup>3</sup> – at 15 bar supply pressure</li></ul> |

Fresh air supplied breathing apparatus (ABM) are used, among other things, during industrial cleaning of process installations. More information can be found in the Handbook on Respiratory Protection by the Industrial Cleaning Foundation (SIR) [4], which is included in Annex B (Legislation and overview of standards for respiratory protection).

## 4 Filter Types

There are filters for particles and aerosols, as well as filters for gases and vapours. Combination filters also exist. Filters can either be a fixed (non-replaceable) part of RPE or can be installed in or attached to the RPE as a replaceable filter. The requirements that filters must meet are established in various standards. These include factors such as the amount of dust allowed to penetrate a particle filter, the duration of protection against a specific gas concentration, and the inhalation resistance. CEN standards also specify the maximum allowable weight of a filter (canister): 300 grams for quarter- or half-face masks, and 500 grams for full-face masks. These weight limits also apply to RPE with dual filter connections: the combined weight of the two filters must not exceed 300 or 500 grams, respectively. Requirements for particle filters are defined in: NEN-EN 143 (for filter canisters [11]) and NEN-EN 149 (for filtering facepieces [12]). The requirements for gas filters are found in: NEN-EN 14387 [13]. For carbon monoxide and filters against radioactive gases and particles, Germany has issued the following standards: DIN 58620 [14] and DIN 58621 [15].

The table below provides an overview of the available filter types.

**Table 5.1: Filter Types with Colour Coding and Application**

| Filter type | Colour code | Application  | Standard                 |
|-------------|-------------|--|--------------------------|
| P           | White       | Particles and aerosols                                 | NEN-EN 143<br>NEN-EN 149 |
| A           | Brown       | Organic gases and vapours, solvents boiling > 65 °C    | NEN-EN 14387             |
| B           | Grey        | Inorganic gases and vapours                            |                          |
| E           | Yellow      | Sulphur dioxide and other acidic gases                 |                          |
| K           | Green       | Ammonia and organic ammonia derivatives                |                          |
| AX          | Brown       | Organic gases and vapours with a boiling point ≤ 65 °C |                          |
| Hg          | Red         | Mercury vapor  |                          |
| NO          | Blue        | Nitrous gases and vapours                              |                          |
| CO          | Black       | Carbon monoxide  | DIN 58620                |
| Reactor     | Orange      | Radioactive iodine                                     | DIN 58621                |

The different gas filter types are also available in combinations, to provide protection against multiple types of gases at the same time.



### 4.1 Particles and aerosols



#### 4.1.1 The operation of particulate filters

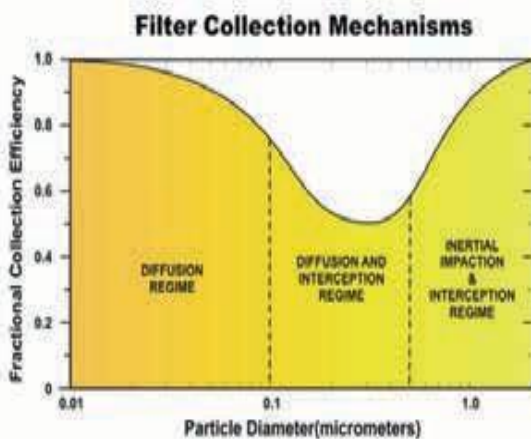
Filters for particles allow air to pass through but largely remove dust from that air. They are not suitable for use against gases or vapours. Not all particles are stopped. The better (more effective) the filter, the smaller the percentage of particles that pass through it.

There are several filtration mechanisms by which particles are captured in filters. The particle size determines which mechanism contributes most to the filter's effectiveness.

**Table 5.2: Filtration mechanisms (source of images: [16])**

| Filtration mechanism  | Description   |
|---|---|
| Diffusion<br>    | The Brownian motion (irregular self-motion) of a particle leads to contact with a filter fibre.                 |
| Interception<br> | Due to the Van der Waals force (force of attraction), the particle is attracted and retained by a filter fibre. |

| Filtration mechanism  | Description   |
|---|---|
|  | Due to its inertia, the particle deviates from the air flow and collides with a filter fibre. |
|  | After contact with a filter fibre, particles are held by a weak electrostatic force.          |



The most difficult particle size to capture (most penetrating particle size; MPPS) depends on the filter medium, airflow speed, and the electrostatic charge of the particle. The effectiveness of particle filters is generally lowest for particles in the range of 0.05 – 0.5  $\mu\text{m}$ . Filter efficiency increases again for both larger and smaller particles. This is illustrated graphically in Figure 5.1. The filter material can capture particles in the nano-range. A major point of concern when protecting against nanoparticles is inward leakage. Adequate protection can only be provided if the user has undergone a face-fit test for the specific type of RPE being used.

**Figure 5.1:** The effectiveness of filtration mechanisms by particle size

#### 4.1.2 Classification and Performance Requirements for Particle Filters

Non-powered filtering devices for particles and aerosols are designated with the label 'P'. There are three classes: P1, P2, and P3, with P3 providing the highest level of protection. For powered devices, only the designation P is used, and the entire RPE system (mask + filter) is tested.

European standards set requirements for, among other things, breathing resistance, filter penetration using test aerosols and inward leakage. These requirements also depend on the type of RPE. Table 5.3 provides an overview of current maximum allowable filter penetration and inward leakage for various types of RPE.

It's important to understand that filter class P3 does not always guarantee the same effectiveness; this also depends on the type of RPE. For example: A FFP3 mask may allow up to 1% filter penetration, whereas a P3 filter used with a half- or full-face mask may allow a maximum of 0.05%.

Additionally, note that half- and full-face masks have separate standards for the filter and the mask, while powered RPE is tested as a complete system.

**Table 5.3:** Performance requirements for respiratory protection against particulates<sup>3</sup>

| Filtering facepieces       | Maximum filter penetration (%) | Standard   |
|----------------------------|--------------------------------|------------|
| FFP1                       | 20                             | NEN-EN 149 |
| FFP2                       | 6                              |            |
| FFP3                       | 1                              |            |
| Half and full-face masks   | Maximum filter penetration (%) | Standard   |
| Half and full-face mask P1 | 20                             | NEN-EN 143 |
| Half and full-face mask P2 | 6                              |            |
| Half and full-face mask P3 | 0.05                           |            |

<sup>3</sup> The table provides several performance requirements for respiratory protection against particles. In addition, there are additional requirements for the total inward leakage for filtering face pieces (NEN-EN 149), for half masks (NEN-EN 140) and for full face masks (NEN-EN 136). For powered half and full-face masks, there are also additional requirements for the situation with the blower unit switched off (NEN-EN 12942). For the sake of readability, this additional information is not shown here.

| Powered hood/helmet or half/full face mask | Total inward leakage (%) | Standard     |
|--|--------------------------|--------------|
| TH1P                                       | 10                       | NEN-EN 12941 |
| TH2P                                       | 2                        |              |
| TH3P                                       | 0.2                      |              |
| TM1P                                       | 5                        | NEN-EN 12942 |
| TM2P                                       | 0.5                      |              |
| TM3P                                       | 0.05                     |              |

FF = filtering facepiece, filtering facepiece, 'snout'  
 TH = turbo helmet/hood, powered hood or helmet  
 TM = turbo mask, powered half or full-face mask

In addition to the filter class (FFP1, FFP2 or FFP3), there are two other designations for filtering facepieces:

- R or NR: masks marked R (re-usable) can be used on multiple days. Masks marked NR (non-re-usable) are for single day use only.
- D: Filter masks marked D are better suited for high dust concentrations, as they are less likely to clog. For this purpose, there is a so-called clogging test, which determines whether and for how long the filter offers protection against high concentrations of dust (e.g. test for 2 hours at a dust concentration of 400 mg/m<sup>3</sup>). If the filter meets the test criteria, the letter D may be added to the filter code.
- Sample marking: FFP2 R D.

Filter canisters with the designation 'RD40' have a coil wire connection with a diameter of 4 cm. These fit face masks that are also equipped with this standard connection.

Filter canisters for half and full-face masks with combination filters for particles and gas may be marked with the symbol with a crossed-out number 2: use on one day (the filter can be used several times within the day).



In the case of powered RPE, the device class determines the filter to be used, and the class is indicated before the filter type, for example: TH2P, TM2P. Filters for powered RPE have different filter penetration requirements than those for the push filters for half and full-face masks. See also Table 5.3.

Particle filters for powered RPE are marked with the letters SL or S. Filters marked S (Solid) can only be used against particles and against water-based aerosols. Filters marked SL (Solid/ Liquid) can also be used against oil-based aerosols.

Particulate filters and filtering facepieces against particles do not protect against dust or oil contains—the particles in which dusts are present with a relatively low boiling point. If, for example, PAH-containing dust is present, it can be expected that PAHs with a boiling point of up to approximately 300 to 400 °C in the form of vapour will still partially penetrate the filter. In the case of substances with a higher boiling point (e.g. benzo(a)pyrene: approximately 500 °C), the breakdown due to evaporation is minimal. If breakdown by evaporation is possible, the particle filter will have to be combined with a suitable gas filter.

#### 4.1.3 Nanomaterials

Nanoparticles are very small particles of the size of 1 to 100 nanometres (one nanometre is one millionth of a millimetre). These particles have special properties that can differ substantially from 'normal' materials. Because little is known about the risks of nanoparticles, they are treated as hazardous substances.

Commissioned by VNO-NCW, FNV and CNV, and with a subsidy from the Dutch Ministry of Social Affairs and Employment, the 'Guide to Safe Working with Nanomaterials and Products' was drawn up in 2017 [18]. This guide states that at least one mask in the FFP3 filter class should be used as RPE.

## 4.2 Gases and vapours

### 4.2.1 The operation of gas and vapour filters

Filters for the capture of gases and vapours mainly contained (impregnated) activated carbon. The coal is processed to obtain a large internal surface area to allow gas molecules to be adhered to. The surface area can be up to 2500 m<sup>2</sup>/gram. Various mechanisms are used to capture gases and vapours. See Table 5.4. A gas filter does not protect against particles; if necessary, it should be combined with a particle filter.



Figure 5.1: Granules of activated carbon

Table 5.4: Adsorption techniques

| Adsorption technique | Description  |
|----------------------|--|
| Physisorption        | <ul style="list-style-type: none"> <li>Hydrocarbons are well absorbed by activated carbon. They penetrate through pores into the filter material and condense on the surface. The capillary action then causes them to be sucked into the micropores. Van der Waals forces (attractive forces between particles) cause the substance to bind to the activated carbon.</li> <li>This mechanism applies to filter types A and AX.</li> <li>Water vapour saturates the filter. High humidity leads to reduced capacity and therefore shorter operating time.</li> </ul> |
| Chemisorption        | <ul style="list-style-type: none"> <li>Molecules of reactive gases react with a chemical coating applied to the active carbon surface. This creates a chemical compound that is so stable that a fixed substance is no longer released from the activated carbon.</li> <li>This mechanism applies to BEKHg gases and vapours (inorganic gases, sulphur dioxide and hydrogen chloride, ammonia, mercury).</li> </ul>  |
| Catalysis            | <ul style="list-style-type: none"> <li>A catalyst (hopcalite) is used in carbon monoxide (CO) filters. Carbon monoxide is converted into the less harmful carbon dioxide in a separate filter stage.</li> </ul>  |

### 4.2.2 Classification and performance requirements for gas and vapour filters

The A, B, E and K filters against gases and vapours are available in three different capacities:

- Class 1: low capacity;
- Class 2: medium capacity;
- Class 3: large capacity.

Low-capacity filters are more likely to be saturated and are more likely to blow. For example, an A2 filter protects against higher concentrations of volatile hydrocarbons for a longer period and/or against higher concentrations than an A1 filter. For gas filters, the number does not indicate the filter quality as it does for particulate filters. Class 3 gas filters are usually too heavy to attach to a face mask but can be worn on a belt.

For gas filters, test gases, test concentrations and test durations are laid down in standards from CEN and DIN. Depending on the type of gas filter (or combination filter), a prescribed type of test gas is passed through the gas filter in a specified test concentration and in a specified ventilation flow rate. A certain breakdown concentration (0.5 to 25 ppm, depending on the type of test gas) must not be exceeded within a set time (20 to 80 minutes, except for mercury: 50 hours).

The test is carried out under controlled conditions in terms of temperature and humidity. The test conditions for A filters are summarized for illustration purposes in Tables 5.5 and 5.6 below. This concerns the requirements of NEN-EN 14387 [13] for interchangeable filters for full or half masks. The BEK filter types are tested with the same concentration levels; However, different test gases are used, and different values apply to the breakthrough concentrations. These requirements are also laid down in NEN-EN 14387. Requirements for filters in blown RPE are included in NEN-EN 12941 (hood/helmet; [19]) and NEN-EN 12942 (mask, [20]).

**Table 5.5: Test Conditions for Type A Gas Filters**

| Filter class   | Test gas    | Minimum breakthrough time (minutes) | Test gas concentration in air (ppm) | Breakthrough concentration (ppm) |
|--|-------------|-------------------------------------|-------------------------------------|----------------------------------|
| <i>for replaceable filters (NEN-EN 14387)</i>        |             |                                     |                                     |                                  |
| A1   | Cyclohexane | 70                                  | 1000                                | 10                               |
| A2   | Cyclohexane | 35                                  | 5000                                | 10                               |
| A3   | Cyclohexane | 105                                 | 5000                                | 10                               |
| <i>for powered RPE (NEN-EN 12941 &amp; EN 12942)</i> |             |                                     |                                     |                                  |
| A1   | Cyclohexane | 70                                  | 500                                 | 10                               |
| A2   | Cyclohexane | 70                                  | 1000                                | 10                               |
| A3   | Cyclohexane | 35                                  | 5000                                | 10                               |

Filter canisters for half- and full-face masks with combination filters for particulate matter and gas may be marked with the symbol with a crossed-out number 2: use on one day (within the day it can be used within the day) filter can be used several times).



The AX filter protects against highly volatile organic gases and vapours (boiling point  $\leq 65$  °C). There are no capacity designations for the AX filter. The AX filter is intended for single use. Be extra careful if there is a mixture of high and low cookers. Ask the supplier for advice.

The CO filter has an indication of the maximum operating time: 20, 60 or 180 minutes. An additional mark 'R' means that the filter can be used several times within a week.

#### 4.2.3 Lifespan of gas filters

Based on the breakthrough time as used in the standard NEN-EN 14387, it is not possible to predict how long a filter can be used in practice. For example, gas filters are tested during the continuous flow of the test gas, while in practice, due to breathing, there is pulsating air flow. Research has shown that in the case of pulsating transit, breakdown is more likely to occur. In practice, the following factors in particular influence the time of use of a filter: the type of gas, vapour or mixture, the concentration at the workplace, the air humidity and the tidal volume. Heavy work leads to a higher respiratory volume and a shorter breakthrough time. A class 1 or 2 gas filter will often blow out within ten to a few tens of minutes at concentrations of around 500 ppm. Class 3 filters last longer, but even with class 3 filters, breakdown can occur within an hour at a concentration of 500 ppm. To continue to provide effective protection, gas filters must be replaced in good time, before a breakthrough occurs.

The UK Health and Safety Executive has carried out a study on the effect of multiple, interrupted exposures on the useful life of filters [21]. Little difference was found in breakthrough time between filters that had been exposed multiple times in one week and filters that had been continuously exposed. The researchers conclude that using a filter several times for a short time in one week does not lead to less protection, compared to continuous use. The effect of exposure to mixtures was also investigated. The least volatile vapours are generally the best absorbed; Thus, the vapor with the higher volatility will be the first to break through. Breakthrough time is shorter when exposed to multiple vapours at the same time: the study found about a halving of the breakthrough time when exposed to two vapours. Finally, it warns of the scenario where a filter is used twice against two different vapours: if the filter is applied first against a weakly absorbent substance and then against a more absorbent substance, the first substance can be expelled from the filter and the user is exposed to high concentrations, even if there has been no breakthrough after the first use of the filter.

It is not safe to rely solely on the user's senses (smell, taste, irritation) before changing a gas filter. Some substances can only be smelled in concentrations above the limit value. Odour thresholds have a large variation between people (order of magnitude of two or more). Also, the odour inhibitor may be increased during prolonged low exposure or due to colds and other illnesses.

Some gas filters are equipped with an 'end of service life' indicator. The user can keep an eye on the indicator himself and replace the filter when the colour changes. In practice, most gas filters are not equipped with such an indicator and a predetermined filter replacement schedule is required.

Legislation in the United States requires an objectively based filter change schedule, based on experimental testing, manufacturer recommendations, or a mathematical model. OSHA's inspection procedure contains more details on how this obligation can be fulfilled [22].

#### 4.2.4 Advice from the Working Group on lifespan

To reduce the chances of a breakthrough, the working group recommends the following good practices regarding the use and useful life of gas filters:

- Assess workplace exposure with measurements or estimates.
- Use gas filters only with an average exposure below 500 ppm. At higher air concentrations, gas filters will quickly become saturated. Then choose an RPE that is independent of the ambient air.
- Determine the maximum operating time of a gas filter, based on:
  - Information from the supplier; or
  - Available programs, e.g. from NIOSH and from vendors such as 3M and MSA. Inputs include the substance to be protected against, the concentration in the air, the air humidity, the tidal volume and characteristics of the filter. In general, it will be wise to see the results of these tools as an upper limit and to apply a safety factor before application in practice.
    - NIOSH MultiVapor™ Version 2.2.5:  
<https://www.cdc.gov/niosh/npptl/multivapor/multivapor.html>
    - 3M Select and Service Life Software: <https://sls.3m.com/selectresultstype> MSA Cartridge Life Expectancy Calculator: <https://webapps.msasafety.com/responseguide/InternationalChemicalCalculator.aspx>
    - MSA Cartridge Life Expectancy Calculator:  
<https://webapps.msasafety.com/responseguide/InternationalChemicalCalculator.aspx>
  - Experimental testing. Especially for mixtures, the most reliable prediction of the duration of use of a filter can be obtained by experimental tests with the substance/product used in practice. Suppliers of respiratory protection can be helpful in carrying out such an examination.
- Determine whether the gas filter can be used on several working days, based on the breakthrough time, duration of use and the properties of the substances being protected against. Use gas filters for a maximum period of one week. Filters that are intended for single use (according to CEN guidelines) may not be reused.
- For repeated use: close the filter from the ambient air during storage to prevent saturation with water vapour.
- If the use-by date indicated on the gas filter has been exceeded, the gas filter must no longer be used.

However, the ability to apply a filtering type of RPE at a certain concentration is not only determined by the probability of breakdown, but also by other factors such as the required protection factor, the IDLH value (Immediately Dangerous to Life or Health), the work to be performed, etc. This is described in the other chapters of this guideline.

### 4.3 Combination filters

The different types of gas and particulate filters can be used in combination. Usually this is in the form of a canister in which the different types of filters are present. Common combinations are a filter against organic vapours and particles (e.g. A2P3) or a filter against various gases/vapours and particles (e.g. A2B2E2K2P3). Combination filters must comply with the standards NEN-EN 14387 (gases and vapours only) and NEN-EN 14387 and NEN-EN 143 (gases, vapours and particles).



**Figure 5.2:** Example of combination filter

### 4.4 Fungi, bacteria and viruses

Fungal spores are around 1-30 µm in size. The diameter of bacteria is around 1 µm. Viruses are smaller, with sizes in the nano-range variety ranging from 5 to 200 nm. This means that particle filters (P) are also effective against exposure to fungi, bacteria and viruses. In practice, at least an FFP2 filtering facepiece is used as respiratory protection, but depending on the situation, a higher degree of protection may be required. More information on the trade-offs can be found in documentation from 3M [23, 24], IRSST [25] and the WHO [26].

## 4.5 Non-occupational health and safety RPE

These RPEs are not personal protective equipment according to the definition of 'personal protective equipment' in the Commodities Act Decree and the Working Conditions Decree. Formally, they fall outside the scope of this directive. To give users some information about this type of product, a short description is given. In 2021, the NVvA Contact Group COVID-19 drew up a vision document with even more information about respiratory protection in the event of COVID-19 [27].

### 4.5.1 *Medical nasal face masks (surgical masks)*

Surgical masks (types I, II and IIR) are primarily a medical device and not a personal protective device. The main goal is to prevent the patient from being infected by the healthcare worker. The mask filters the air that is exhaled and thus protects the patient and the environment from microorganisms.

The surgical masks fit less tightly to the user's face than FFPx face masks. As a result, they are less effective for protecting the healthcare provider against external viruses. This is because particles from the air can still enter through the sides of the mask. An appendix to the COVID-19 guideline of the RIVM [28] and the Guideline "Personal protection in the (outpatient) inpatient setting due to SARS-CoV-2" of the Dutch Federation of Medical Specialists [29] state when a surgical mouth mask is sufficient and when an FFPx mask is necessary.

The packaging must state that it is a face mask for medical use. It has a CE mark on it. The products are tested based on the standard NEN-EN 14683 [30] and must comply with the European Medical Device Directive [31].

The surgical masks with the type designations II and IIR have a higher 'Bacterial filtration efficiency' (BFE) than agents of the type I. Surgical masks of the type II-R protect the mouth and nose from any splashes of body fluids of the patient.

### 4.5.2 *Non-medical mouth-nose masks*

Non-medical face masks are means to be used by the general population in public indoor spaces and public transport.

These products do not have official indications. Except for the statement that they are only intended for civilian use (i.e. not for personal protection or medical purposes). There is also no CE marking or medical claim on the packaging or a text that refers to a standard. These products are not subject to any legal requirements regarding the quality and protection they offer.

A non-medical face mask, like surgical masks, does not protect the wearer of the mask, but the people around the wearer (when used carefully). A non-medical face mask is always an addition to other hygiene measures. Especially in the period 2020 – 2022 at the time of the COVID-19 pandemic, non-medical face masks were prescribed as part of the Dutch government's Corona policy.

Non-medical masks are consumer items; they fall under the Dutch Commodities Act. Of course, the material must not pose a hazard during use. NEN has described two specifications that non-medical mouth-nose masks preferably meet [32].

## 5 Protection Factors

### 5.1 What is a Protection Factor?

When using respiratory protective equipment (RPE), contaminants from the surrounding air can still penetrate the equipment. RPE does not provide 100% protection. The level of protection is expressed as a protection factor, which is the ratio between the concentration of contaminants outside the RPE and the concentration inside it. However, the extent to which contaminants penetrate an RPE is not fixed and depends on several factors, including:

- The design of the equipment;
- The type of filter used (for dependent respiratory protection);
- The fit to the user (e.g., size and seal);
- The way it is used;
- Maintenance practices;
- The level of training of the user.

All these factors should be part of a respiratory protection programme (see chapter 2), in which the appropriate RPE is selected based on the nature of the contamination and the tasks to be performed. This chapter discusses the different types of protection factors.

A protection factor provides an indication of the level of protection that can be expected in the workplace. It serves as a tool to help select the appropriate RPE.

There are different types of protection factors, each with its own definition. The following sections of this chapter outline these various protection factors. Additionally, the working group's preferred protection factor will be indicated, along with key issues that occupational hygienists should consider when incorporating these factors into their recommendations.

### 5.2 Types of Protection Factors

There are various types of protection factors. It is important to use the underlying definitions of these different protection factors correctly. The following protection factors are distinguished:

- The Nominal Protection Factor (NPF)
- The Workplace Protection Factor (WPF)
- The Assigned Protection Factor (APF)
- The Simulated Workplace Protection Factor (SWPF)
- ISO Protection Factors

#### 5.2.1 Nominal protection factor (NPF)

The Nominal Protection Factor (NPF) is a widely used protection factor. Producers or suppliers always indicate the NPF values in their documentation but may also indicate other protection factors.

The standard NEN-EN 529:2005 provides the following definition of the NPF:

*The NPF is the ratio number derived from the total inward leakage (TIL). These values are laid down in the specific standards for the different types of RPE.*

The relationship between the nominal protection factor and the total inward leakage is expressed as follows:

$$NPF = \frac{100}{TIL \text{ (in \% )}}$$

The total inward leakage is determined by three key aspects:

1. Filter efficiency – This refers to the effectiveness of the filter in removing contaminants. This includes the classes for particle filters: class 1 filters 80%, class 2 94% and a P3 filter removes 99.95% of the particulate matter.
2. Mask leakage – This refers to leakage within the product itself (mask + filter). This could be a leak between the visor and the frame of the full-face mask or between the mask's rubber seal and the

valve seat.

3. Leakage due to improper fit – This occurs when the mask does not fully seal against the user's face, allowing contaminants to enter. This type of leakage is assessed during practical testing.

In the laboratory RPE is tested to determine whether it meets the NPF value specified for that type of equipment. However, there are differences between the protection measured in laboratory tests and the actual protection observed in the workplace. In general, workplace protection tends to be lower than what laboratory tests suggest. Possible reasons for this discrepancy include:

- Use of new RPE in laboratory tests vs. older, potentially less well-maintained RPE in real-world conditions.
- Differences in training and supervision, which can affect correct usage.
- Variations in activities and working postures, which can influence the seal of the mask on the face.

### 5.2.2 Workplace protection factor (WPF)

In the standard NEN-EN 529:2005 the Workplace Protection Factor (WPF) is defined as follows:

*The WPF is the ratio between the concentration (outside the facepiece, in the breathing zone) of a chosen hazardous substance and its concentration within the facepiece of a properly functioning respiratory protective device, when worn and used correctly in the workplace.*

These are actually measured concentrations, measured in practical situations. The protection factor in the workplace is calculated using the following formula:

$$\text{WPF} = \frac{\text{Concentration outside the facepiece, in breathing zone}}{\text{Concentration in the facepiece}}$$

There is no standardised method for determining the WPF. Studies on WPF are typically conducted by independent research institutions or universities. Since it is not scientifically valid to base a WPF on just a few measurements, comparing results across different studies is often challenging.

### 5.2.3 Assigned Protection Factor (APF)

In addition to the Nominal Protection Factor (NPF) and the Workplace Protection Factor (WPF), the Assigned Protection Factor (APF) is defined in NEN-EN 529:2005 as:

*The APF is the expected level of respiratory protection that can realistically be achieved in the workplace by 95% of properly trained and supported users who wear using a properly functioning and correctly fitting respirator.*

The APF is based on the 5<sup>th</sup> percentile of the workplace protection factor (WPF).

The APF is awarded based on research carried out when used under workplace conditions. To this end, in many situations (several people and various workplaces), the degree of protection achieved during normal work is measured. This is done by simultaneously measuring the concentration inside and outside the RPE. The ratio between outdoor and indoor concentration is the workplace protection factor. This factor can vary greatly between different measurements and between individuals.

The APF considers all potential sources of leakage from the face mask (e.g. leakage along the face seal, filter penetration, valve leakage). The APF does not consider other factors that may impair protection, such as poor maintenance, failure to follow the manufacturer's instructions, and failure to wear the mask during the exposure period. The APF is a percentage value. For most of the group, the degree of protection achieved is therefore (much) more favourable than the protection factor granted, but it is possible that part of the group is not offered sufficient protection. This can be overcome by carefully fitting RPE and performing face-fit tests and using and maintaining RPE in accordance with the instructions for use.

When results of field studies on the protection factor of a specific RPE are not available, the APF can be calculated by dividing the NPF by a given safety factor. In practice, a factor between 5 and 50 is used as a rule of thumb. This means that, in general, a safety factor of between 5 and 50 is used to

correct for the difference in conditions in the TIL/NPF measurements and the situation in practice. Here the assumption is made that circumstances in practice, such as the improper use of resources, the perhaps not optimal fitting, the performance of activities that may lead to lower protection (e.g. strenuous work or work in narrow spaces) will lead to a factor of 5-50 less protection.

The research to arrive at a APF is very labour-intensive. In addition, there are differences in starting points used when designing a study to determine the APF of a particular type of RPE. In the United States, the APFs defined in federal law are used [33]. In Europe, countries use different starting points, which leads to differences in the values of APF. See the table below from NEN-EN 529:2005.

**Table C1** of NEN-EN 529:2005

| Standard  | Description   | Class                                    | NPF                     | Assigned Protection Factors used in some countries |      |                  |      |    |
|---|---|--|-------------------------|--|------|------------------|------|----|
|   |   |  |                         | FIN  | D    | I                | S    | UK |
| EN 149  | Filtering half mask   | FF P1                                    | 4                       | 4  | 4    | 4                | 4    | 4  |
|   |   | FF P2                                    | 12                      | 10   | 10   | 10               | 10   | 10 |
|   |   | FF P3                                    | 50                      | 20   | 30   | 30               | 20   | 20 |
| EN 405  | Valved filtering half mask  | FFGasX P1                                | 4                       |  | 4    | --               |      | 4  |
|   |   | FFGasX                                   | 50                      |  | 30   | --               |      | 10 |
|   |   | FFGasX P2                                | 12                      |  | 10   | --               |      | 10 |
|   |   | FFGasX P3                                | 33                      |  | 30   | --               |      | 10 |
| EN 140 (mask)<br>Filters:<br>EN 141 *)<br>EN 143<br>EN 371 & 372 *)<br>EN 14387<br>EN 12083 | Half mask and quarter mask with filter  | P1                                       | 4                       | 4  | 4    | 4                | 4    | 4  |
|   |   | P2                                       | 12                      | 10   | 10   | 10               | 10   | 10 |
|   |   | P3                                       | 48                      | 20   | 30   | 30               | 20   | 20 |
|   |   | GasX                                     | 50                      |  | 30   | 30               |      | 10 |
|   |   | GasX P1                                  | 4                       |  | 30   | --               |      | 10 |
|   |   | GasX P2                                  | 12                      |  |      |                  |      |    |
| EN 1827   | Filtering half mask without inhalation valves   | FM P1                                    | 4                       |  | 4    | --               |      | 4  |
|   |   | FM P2                                    | 12                      |  | 10   | --               |      | 10 |
|   |   | FM P3                                    | 48                      |  | 30   | --               |      | 20 |
|   |   | FM GasX                                  | 50                      |  | 30   | --               |      | 10 |
|   |   | FM GasX P1                               | 4                       |  |      |                  |      |    |
|   |   | FM GasX P2                               | 12                      |  |      |                  |      |    |
|   |   | FM GasX P3                               | 48                      |  |      |                  |      |    |
| EN 136 (mask)<br>Filters<br>EN 141 *)<br>EN 143<br>EN 371 & 372 *)<br>EN 14387<br>EN 12083  | Full face mask (all classes)  | P1                                       | 5                       | 4  | 4    | 4                | 4    | 4  |
|   |   | P2                                       | 16                      | 15   | 15   | 15               | 15   | 10 |
|   |   | P3                                       | 1000                    | 500  | 400  | 400              | 500  | 40 |
|   |   | GasX                                     | 2000                    | 400  | 400  | 400              | 500  | 20 |
|   |   | GasX P1                                  | 5                       |  | 400  | --               |      | 20 |
|   |   | GasX P2                                  | 16                      |  |      |                  |      |    |
| EN 12941  | Powered filtering device incorporating a hood or a helmet   | TH1                                      | 10                      | 5  | 5    | 5 <sup>b</sup>   | 5    | 10 |
|   |   | TH2                                      | 50                      | 20   | 20   | 20 <sup>b</sup>  | 20   | 20 |
|   |   | TH3                                      | 500                     | 200  | 100  | 200 <sup>b</sup> | 200  | 40 |
| EN 12942  | Powered assisted filtering device incorporating full face mask, half mask or quarter mask                         | TM1                                      | 20                      | 10   | 10   | 10 <sup>b</sup>  | 10   | 10 |
|   |   | TM2                                      | 200                     | 100  | 100  | 100 <sup>b</sup> | 100  | 20 |
|   |   | TM3                                      | 2000                    | 1000   | 500  | 400 <sup>b</sup> | 1000 | 40 |
| EN 14593-1  | Compressed air line breathing apparatus with demand valve – Part 1: Apparatus with a full-face mask               |  | 2000                    | 1000   | 1000 | 400              | 1000 | 40 |
| EN 14593-2  | Compressed air line breathing apparatus with demand valve – Part 2: Apparatus with half mask at positive pressure |  | 200                     |  |      |                  |      |    |
| EN 14594  | Continuous flow compressed airline breathing apparatus  | 1A / 1B<br>2A / 2B<br>3A / 3B<br>4A / 4B | 10<br>50<br>200<br>2000 |  |      |                  |      |    |
| EN 138  | Fresh air hose breathing apparatus  | Half mask                                | 50                      |  | 100  | --               |      | 10 |
|   |   | Full face mask                           | 2000                    | 500  | 1000 | 400              | 500  | 40 |
| EN 269  | Powered fresh air hose breathing apparatus incorporating a hood   | Hood                                     | 200                     |  | 100  |                  |      |    |

| Standard | Description  | Class  | NPF   | Assigned Protection Factors used in some countries |                    |      |     |      |
|----------|--|--|-------|--|--------------------|------|-----|------|
|          |  |  |       | FIN  | D                  | I    | S   | UK   |
| EN 137   | Self-contained open circuit compressed air breathing apparatus   | Negative pressure command<br>Positive pressure command | 2000  |  | >1000 <sup>a</sup> | 400  |     | 40   |
|          |  |  | 20000 |  | >1000 <sup>a</sup> | 1000 |     | 2000 |
| EN 145   | Self-contained closed-circuit compressed oxygen/nitrogen breathing apparatus   |  | 20000 | 500  | >1000 <sup>a</sup> | 400  | 500 |      |
| EN 402   | Self-contained open circuit compressed air breathing apparatus with full face mask or mouthpiece assembly for escape |  | 20000 |  | >1000 <sup>a</sup> | --   |     |      |

Countries: FIN = Finland; D = Germany; I = Italy; S = Sweden; UK = United Kingdom

\*) superseded by NEN-EN 14387

- a. Comment from BGR (2004) "Rules for the uses of respiratory protective devices": These devices can be used generally, particularly when filtering devices cannot provide sufficient protection. A restriction of the field of use due to high concentrations of harmful substances cannot be derived from the use of these types of devices as far is known until now. This applies to devices with normal and positive pressure.
- b. Values based on old EN 146 for apparatus THP1/THP2/THP3 and TMP1/TMP2/TMP3.

Research into the justification of the APF values has been conducted, particularly in the United States and the United Kingdom.

The ANSI/OSHA-APF values from the United States form a well-supported and relatively complete dataset. The APF values and usage guidelines are listed in the OSHA Guidance 3352-02 [34]. The justification of these APF values has been extensively documented in the OSHA Final Rule on Assigned Protection Factors [35]. However, the downside is that the research is based on types of respiratory protection and filters used in the US, which sometimes differ from those commonly used in Europe. Additionally, the regulations in the US are stricter regarding the fitting and use of respiratory protection; for example, face fitting tests are a legal requirement in the US. For these reasons, the APF values from the US are not directly applicable to the European situation.

This publication from 3M [36] describes in more detail the background and differences regarding protection factors between the US and Europe.

What stands out in NEN-EN 529:2005 is that, in Annex C, several countries (United Kingdom, Germany, Finland, Italy, and Sweden) assign different APF values for the same type of respiratory protection. The United Kingdom and Germany have established a APF value for 21 types of respiratory protection. Finland, Sweden, and Italy have done so for 10 types of respiratory protection. In the Netherlands, no APF values have been established.

The German APF values differ from the UK values for 13 of the 21 types. Notably, for types with higher protection values, the UK values are lower than the German values. This means that in the United Kingdom, the protection provided by respiratory protection is evaluated as lower than in Germany. The publication HSG53 (Respiratory protective equipment at work) from the UK Health and Safety Executive [37] provides a clear overview of the APF value per type of respiratory protection. In Germany, this is described in the publication 112-190 'Benutzung von Atemschutzgeräten' by DGUV [38].

Research on protection factors in Europe has, to the best of knowledge, only been carried out in the United Kingdom. This research primarily relied on results from actual protection measurements of respiratory protection devices in workplaces.

In Germany, to the best of knowledge, no research has been carried out on APF values. Those involved in drafting the standard EN 529:2005 indicate that in Germany, the APF values are based on the NPF values, applying safety factors. These safety factors vary from 1 to 4. The reasoning behind the chosen safety factor is unknown [39]. The application of these APF values is part of a respiratory protection program as described in the DGUV Regulation 112-190 [38].

Clayton et al. [40] expressed this well in the view of the working group: the approach of BSI (British

Standard Institute) has led to conservative and, in the eyes of some, to cautious APF values. The advantage of these values is that, if they are wrong, the APF is on the cautious side, which should lead to lower exposure for users of respiratory protection. At the same time, to achieve higher protection factors, more extensive respiratory protection programs are needed, along with the associated effort and costs. Conservative APF values are on the safe side but lead to additional costs. The higher APF values from other countries (such as Germany) can be seen as optimistic and may put users of respiratory protection at risk unless they are thoroughly supported with data from WPF/SWPF studies.

The differences in deriving and establishing protection factors led, in 2009, to a research project at the European level by the PEROSH research group. The aim was to establish workplace protection factors accepted across Europe. Another goal was to determine the effect and effectiveness on user protection by comparing the 'as is' situation with the situation after the user was trained in the correct use of respiratory protection [41]. Due to budget issues, this research was discontinued.

#### **5.2.4 Simulated Workplace Protection Factor (SWPF)**

In Europe, there is no standardized definition of the SWPF. The following definition of SWPF is used by the U.S. government organization OSHA [35]:

*A study conducted in a controlled laboratory environment in which sampling is performed both inside and outside the mask while the user of the respiratory mask performs a series of established exercises. The laboratory environment is used to control many of the variables encountered in workplace studies, while the exercises simulate the work activities of respiratory mask users. This type of research aims to determine the optimal performance of respiratory masks by reducing the impact of sources of variability through maintaining strictly controlled research conditions.*

SWPF studies are only applicable to specific applications or activities, with well-defined respiratory protective equipment (RPE). This makes it difficult to extrapolate the results of SWPF studies to other applications.

To determine SWPFs, measurements are carried out with a reasonable number of test subjects performing a predefined series of actions or procedures. The protection factor is calculated per action based on the ratio of the measured concentrations outside and inside the mask. Usually, when determining the SWPF, the same definition is used as for the APF, and a 95th percentile value is derived.

In the Netherlands, a SWPF study was conducted in 2016 by TNO on behalf of the Ministry of Social Affairs and Employment [42]. This study investigated the protection factors for eight types of respiratory protective equipment (RPE) used in the asbestos industry. This included both dependent and independent RPE. The research showed significant differences in protection factors between the investigated brands and types of RPE. On average, independent air systems offer better protection than dependent RPE (a factor of ten), but the study also revealed that a dependent RPE can perform better than an independent one.

#### **5.2.5 ISO Protection Factors**

With the new ISO standards (see Annex B), a completely new way of evaluating RPE (respiratory protective equipment) is emerging: the focus is no longer on the protective equipment itself, but on the user. The tasks/actions, metabolism, and the agent are determining factors for selecting the correct RPE. The current protection factors, NPF and APF, are no longer defined in the new ISO standards; instead, the ISO standards rely on protection classes and protection levels.

The ISO standards are ultimately developed through collaboration and participation from all standardization bodies worldwide. Since this new standard will also fall under the "Vienna Agreement" between ISO and CEN, the ISO standards will also be implemented in Europe. However, it is currently unclear when this will take place.

All RPE are classified based on the following characteristics:

- The protection class (PC);
- The physical effort that can be performed with the RPE (work rate; W);

- The shape and design of the mask (respiratory interface; RI) – this provides information about the coverage area (e.g., half-mask, full-face mask) and the fit.

Gas filters are classified according to the type and test gas concentration of the respective test gases. Depending on the type of gas filter, there are up to four classes with corresponding test gas concentrations.

For all RPE, there are six protection classes, numbered from PC1 (low protection) to PC6 (highest protection). The protection class is based on the total inward leakage (TIL). The lower the TIL<sub>max</sub>, the better the protection class and the corresponding protection level. Information over the six protection classes is shown in Table 6.1. The idea is that the number of the protection level can be applied in the same way as an APF value.

**Table 6.1: ISO Protection Classes and Protection Levels**

| Protection class | TIL <sub>max</sub> (%) | 1/TIL <sub>max</sub> | Safety factor | Protection level |
|------------------|------------------------|----------------------|---------------|------------------|
| PC1              | 20                     | 5                    | 1.25          | 4                |
| PC2              | 5                      | 20                   | 2.0           | 10               |
| PC3              | 1                      | 100                  | 3.3           | 30               |
| PC4              | 0.1                    | 1000                 | 4.0           | 250              |
| PC5              | 0.001                  | 10000                | 5.0           | 2000             |
| PC6              | 0.0001                 | 100000               | 10.0          | 10000            |

At the time of writing, there are no RPE available according to ISO standards.

In the preliminary Dutch standard NVN-ISO/TS 16975-1 [5], the current protection factors from EN 529 are compared in annex K and classified in the protection classes. It also provides further clarification in the determination and use of safety factors. The DGUV publication 212-190 [38] describes the application of the ISO standards for classification and selection of respiratory protection.

### **5.2.6 Effectiveness of protection factor: depending on wearing time**

Respiratory protection is only effective if the product is used consistently during exposure. Figure 6.1 (next page) is based on an article by Brown [43] and gives a picture of the effective protection factor when the RPE is not worn for part of the time. When an RPE with APF of 20 is not used for 5% of the exposure time, the effective protection factor drops from 20 to 10. With RPE with higher APF values, the effect of non-wearing increases:

- With an APF of 100 and a non-wear period of 1%, the effective protection factor decreases from 100 to 50 and with a non-wear period of 5%, the effective protection factor of the RPE is reduced to below 20.
- With an APF of 1000 and a non-wear period of 1%, the effective protection factor decreases to below 100.

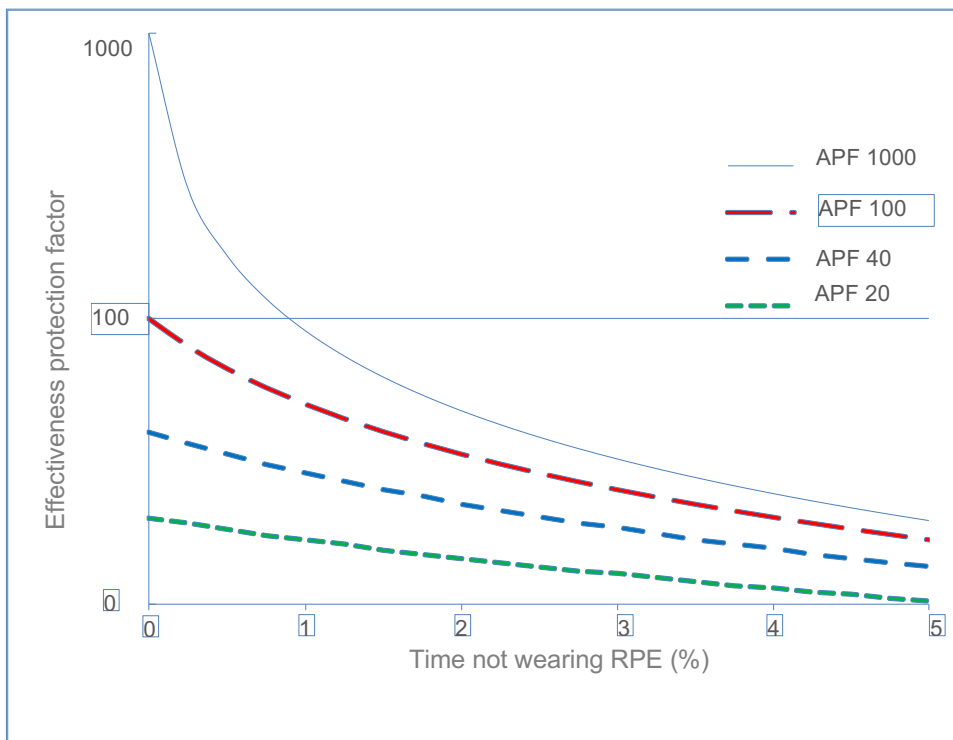


Figure 6.1: Effective Protection Factor Protection Factor in case of non-wearing RPE

### 5.3 Advice from the working group on the use of protection factors for selecting RPD

To ensure adequate protection under workplace conditions, it is essential to make the right choices. Unlike other countries such as the United States, the United Kingdom, and Germany, there is no law or regulation in the Netherlands prescribing which protection factors should be used. The working group provides advice in this section on which protection factors to use, to assist in selecting the right respiratory protection within a respiratory protection program.

The American APF values have the disadvantage of not being tailored to the RPDs used in Europe. In America, different minimum performance requirements [33] apply compared to Europe (EN standards).

The NPF values from NEN-EN 529:2005 are based on laboratory research and are therefore far removed from practical use.

The APF values mentioned in NEN-EN 529:2005 were established using Workplace Protection Factor studies and/or expert judgment. Because different source data and various experts were involved in determining the APF values, the figures differ from country to country.

- Since Finland, Italy, and Sweden have only established a limited number of APF values in NEN-EN 529:2005, it is not useful to adopt the APF values from these countries.
- The APF values from Germany and the United Kingdom differ. In Germany, as far as is known, no specific research has been conducted on APF values, and the APF values are based on the NPF values with the application of a safety factor. When the working group inquired with DGUV about the considerations that led to the establishment of the APF-Germany values, it turned out that these could no longer be traced. In the United Kingdom, the APF values are based on research conducted in actual workplace situations 'as is'. Several requests have been made within the UK to the HSE to increase the APF values. To date, the HSE has rejected these requests, reasoning that a higher step should be taken in the STOP strategy by reducing the need for respiratory protection, rather than increasing the range of respiratory protection.

The working group considered using the German APF values for situations with an effective respiratory protection program. However, SWPF research shows that there can be significant

differences in protection factors between different brands and types of RPD within the same class. It is possible that specific RPDs may offer a lower protection factor than the German APF values. For example, TNO's research for the asbestos industry revealed that for all five types of full-face masks with a motor unit tested, the protection factor was higher than the United Kingdom's APF value (APF = 40); at the same time, for two of the five types tested, the protection factor was lower than the German APF value (of 500).

Therefore, as a starting point, the choice remains for the 'conservative' APF values from the United Kingdom. In cases where well-founded data is available regarding the protection factor of a specific brand and type of RPD, for example, from SWPF research for a company or industry, this information can be used to justify deviation from the standard APF values.

The new, global ISO standards will change the landscape of RPD in the future. However, it is still not known when these standards will come into effect in Europe. The disadvantage of opting to use the new ISO standards is that there are currently no suppliers using the new protection classes PC1 to PC6 with the corresponding protection levels. Once the ISO standards come into effect and RPD produced according to these standards becomes available on the market, there will be global consistency in the protection levels of RPD.

The working group **advises** the following based on the above:

- Do not use the American APF values.
- Do not use the NPF values from NEN-EN 529:2005.
- Generally use the APF values from the United Kingdom in NEN-EN 529:2005.
- If specific information is available about the protection factor of the applied brand and type of RPD (e.g., from SWPF research), this can be used to justify and apply a higher APF value for that RPD.
- Conduct SWPF research at the company or industry level on the types of RPD in use.
- Stay informed about the developments with the new ISO standards and research on RPD protection factors.
- Ensure that RPD is consistently used during exposure.

The assigned protection factor is only one aspect of a particular type of RPD. When selecting and using RPD, other important factors play a role, which determine the comfort and discomfort that the use of the RPD brings during work. The new ISO standards take these aspects into account when choosing an RPD. In the ISO standards, the focus is no longer on the RPD itself, but on the user, the physical load, and the fit. Chapter 2 presents the framework of an RPD program, addressing all the factors involved.

## 6 Toxicity of the Substance(s) in the Selection of RPE

### 6.1 Nature of the Substance

To select the correct type of respiratory protective equipment (RPE) and use it responsibly, knowledge is required about the nature of the hazardous substance or gas for which protection is necessary. Often, there will be a mixture of different types of substances, vapours, and gases. In such cases, an assessment must be made for each component.

The RPE must provide adequate protection. Table 4.1 (in chapter 4) presents the available filter types. Choose the filter type that corresponds to the properties/description of the substance. This means that some knowledge of the substance's properties must be known to make an informed choice.

### 6.2 Occupational Exposure Limit Values

The purpose of wearing a respiratory protective device (RPD) is to protect the user in such a way that the exposure limit of the substance(s) is not exceeded during inhalation. To achieve this, it is necessary to know which limit value(s) apply.

There are several types of limit values that play a role in this:

- Time-Weighted Average over 8 Hours (TWA-8h): This type of limit value applies to an 8-hour workday and a 40-hour workweek.
- Short-Term Exposure Limit (STEL): This is the 15-minute time-weighted average.
- Ceiling Value (C, 'Ceiling Value'): Exceeding this concentration must be prevented under all circumstances.
- IDLH Value (Immediately Dangerous to Life or Health): This value, established by the US NIOSH [44] (<https://www.cdc.gov/niosh/idlh/default.html>), indicates the concentration of a substance above which the ability of workers to escape without respiratory protection is adversely affected, and maximum respiratory protection is required. The IDLH value applies for an exposure duration of thirty minutes.

In the Netherlands, legal exposure limit values are established in Annex XIII of the Dutch Working Conditions Decree [45] (<https://wetten.overheid.nl/BWBR0008587>). There is a separate list of limit values for carcinogenic substances (list B1 and B2) and for allergenic substances (list C).

If there are no legal exposure limits, the employer must establish health-based private limits/business standards. The Dutch Labour Inspectorate [46] describes the following order to establish a business standard:

1. Health-based limit values, set by the Health Council of the Netherlands, or until 2019 the European Scientific Committee for Occupational Exposure (SCOEL) and, from 2019, the Risk Assessment Committee (RAC) [47].
2. Foreign limit values, based on a health rationale. Foreign limit values (with and without health substantiation) can be found via:
  - The Social and Economic Council's Substances Limit Values at the Workplace database [48]. It contains the substances for which a Dutch legal limit value has been set. The database also lists the limit values that were used as legal or administrative limit values until 1 January 2007. Since the introduction of the new system on 1 January 2007, these values have been covered by the private system. These values can serve as a basis for setting a firm limit value. Finally, the database presents the limit values applied in several EU and other countries.
  - The IFA GESTIS Limit Value Database [49]. It publishes the publicly available limit values of 27 countries (European and international).
  - The ACGIH [24] publishes an annual new edition (paid) of the publication "Guide to Occupational Exposure Values", which presents a TLV value for each substance, as well as the limit values of other organisations (OSHA, NIOSH, DFG, OARS). All of them, except for the MAK Werte from DFG (Germany), are limit values from the United States. In addition to the TLVs, the other limit values are also available free of charge.
3. DNELs (Derived No-Effect Levels). The "Derived No-Effect Level" is the exposure level to a substance above which people should not be exposed. Manufacturers or importers of more than ten tons per year in Europe must establish DNELs for the substance subject to mandatory registration for tasks involving the substance and mention these in the chemical safety report and

safety data sheet (part of REACH; the European regulation concerning the production and trade of chemicals). DNELs are established based on a fixed set of data. DNELs can be found in the REACH dossier of the substance on the ECHA website, the REACH helpdesk (<https://chemischestoffengoedgergeld.nl>), and in Safety Data Sheets.

4. Scientific publications.
5. Kick-off values, based on a (group) comparison of hazard statements of the substances, developed by and available in the DOHSBase Online program (<https://www.dohsbaseonline.com>). The methodology used to derive kick-off values has been published [50]. There are costs associated with the use of this software.

When determining the applicable exposure limit, the duration and level of exposure are important. In any case, the IDLH value of the substance inside the mask must not be exceeded.

IDLH values (Immediately Dangerous to Life or Health) are established (by NIOSH) to:

- Ensure that the worker can escape from a contaminated environment in the event of an ABM failure, and
- Indicate a maximum level above which only a very reliable respiratory apparatus, offering maximum protection to workers, is permitted.

If the IDLH value is expected to be exceeded at the workplace, RPE with fresh air supply (breathing apparatus) should be used. Filtering agents (with or without air injected) may not be used. In addition, an escape mask worn by the employee must be used to be able to leave the room safely in the event of failure of the RPE.

The Dutch Industrial Cleaning industry [4] uses so-called PAC values instead of limit values or IDLH values. Protective Action Criteria (PAC) are values set by the U.S. Department of Energy and are based on AEGLs and ERPGs. They are used to anticipate and respond to the uncontrolled release of hazardous substances and/or exposure to them.

Volandis, the Dutch knowledge and advisory centre for sustainable employability in the Construction and Infrastructure sectors, indicates that carcinogenic substances (such as quartz dust) can cause health damage even at very low concentrations. For these substances, exposure limits are also established. However, even at concentrations below the limit, the use of ABM may still be necessary for carcinogenic substances. Volandis advises selecting a protective device and filter type that reduces the concentration inside the mask to well below the exposure limit (10% or lower) [51].

### 6.3 Exposure (concentration outside the filter)

Wearing RPE is intended to protect the user so that the exposure inside the RPE does not exceed the established limit value. Therefore, it is necessary to determine the concentration(s) to which the user is exposed. Generally, the highest expected concentration must be determined. This highest concentration must remain below the Maximum Use Concentration (MUC) of the RPE. The MUC is the maximum concentration against which the RPE can provide protection. The MUC is determined by the protection factor of the RPE and the limit value (OELV) of the substance using the following formula:  $MUC = APF * OELV$ .

The hazard properties of the substance determine whether the MUC is determined on the basis of a peak concentration or an average concentration. For substances with an acute effect, the peak concentration is important. For substances with a long-term effect, this is the average concentration during work.

Preferably, exposure is measured. This needs to be done carefully. Without a good understanding of the expected concentrations, it is not possible to select an RPE in a responsible manner. If the average concentration is important, the strategy and assessment should be carried out based on, for example, the standard NEN-EN 689 [52] or the NVvA/BOHS guideline [53].

If exposure to several substances with the same health effect is possible at the same time, the measured or calculated exposure should be assessed using the 'addition rule' (Dutch Working Conditions Regulation, Annex XIIc) [45].

$$\sum_1^n \frac{\text{Concentration}}{\text{OELV}} < 1$$

The fraction  $\frac{\text{Concentration}}{\text{OELV}}$  which is the highest is dominant for the choice of the limit value, since it is this exposure that makes the largest contribution to the total exposure.

If exposure measurements are carried out, the strategy and assessment should be carried out in accordance with the most recent version of the standard NEN-EN 689 [52].

For situations where performing measurements is technically or organizationally difficult or not possible, exposure estimation models can be used. When using quantitative estimation methods, it is important to use a method that is sufficiently reliable. Since 2013, there have been several validation studies to assess the reliability of quantitative exposure estimation models [54], [55]. This showed that none of the models is sufficiently consistent across the entire scope. The user of a model must clearly indicate how the results of the model have been interpreted and make clear for which situations the model is suitable (e.g. because the result is satisfactory - the limit value is far below the limit value) and for which situations additional substantiation (measurements) is required.

The study by Lee et. al from 2019 (part II) [56] indicates that Stoffenmanager (<https://stofenmanager.com>) and Advanced REACH Tool (ART) (<https://www.advancedreachtool.com>) can be considered as higher tier models. Recent developments are Chemrade (<https://www.chemrade.nl>) and Trexmo (<https://www.exposuremodel.com/about/>): these software applications compute multiple exposure models simultaneously. By the way, there are costs associated with the use of Stoffenmanager and Chemrade. ART and Trexmo are free.

The measured or calculated exposure must be recorded in a dossier, as well as the limit value and the data on which this limit value is based.

## 6.4 Determining the required protection factor

Now that we know which limit value applies and what exposure there is outside the RPE during handling, it is possible to calculate the degree of protection that the RPE must have. This is also known as the Minimum Required Protection Factor (MRPF). To determine the MRPF, use the following formula:

$$\frac{\text{Concentration outside the mask}}{\text{OELV}} = \text{MRPF}$$

In which:

- Concentration: the measured or calculated exposure concentration outside the mask.
- OELV: the relevant occupational exposure limit value. This depends on the duration of the operation or the time that the RPE must be worn.
- MRPF: Minimum Required Protection Factor. Compare this value with the applied Protection Factor (APF). See the advice of the working group on the preference for an assigned protection factor (APF, section 6.3) and table C1 from the standard NEN-EN 529:2005 (in section 6.2.3).

Choose the type of RPE with an assigned protection factor (APF) greater than the calculated MRPF. If there are no filtering agents that meet these requirements, opt for self-contained respiratory protection.

In addition, the maximum concentration against which the RPE can be used can be calculated. This is also known as the Maximum Use Concentration (MUC). This value is necessary to check whether the chosen RPE still offers sufficient protection during worst-case concentrations. To determine the MUC, use the following formula:

$$\text{APF value} * \text{OELV} = \text{MUC}$$

In which:

- APF value: the applied protection factor (APF) determined using table C1 of the NEN-EN529:2005 standard.
- OELV: the relevant occupational exposure limit value. This depends on the duration of the operation, or the time that the RPE has to be worn.

- MUC: Maximum Use Concentration. The maximum concentration against which the RPE provides adequate protection.

Compare the MUC to the worst-case concentration to determine if the type of RPE provides adequate protection. If this is not the case, choose a type of dependent respiratory protection with a higher rated protection factor (APF) or opt for independent respiratory protection.

## 6.5 Asbestos

The Dutch Certification Scheme for the Process Certificates for Asbestos Inventory and Asbestos Removal (elaboration of Article 1.5a, part c of the Dutch Working Conditions Decree) [57] specifies specific prescribed RPE that must be used when working with asbestos. This specific regulation should be complied with, even if the prescribed RPE differs from the type of RPE that would be selected under this guideline.

## 6.6 Working in or with contaminated soil

When working in or with contaminated soil and/or groundwater, the CROW 400 [59] must be followed. Depending on the expected evaporation (which must be calculated), the correct RPE must be determined by a competent person. The CROW 400 contains guidelines on which type of RPE can be used, with which filter. Additional requirements have also been set in the case of asbestos, carcinogenic substances or substances with an H notation. Requirements are also set for the medical examination and training that employees must undergo.

## 6.7 Working according to SIR (Industrial Cleaning Foundation)

The SIR Respiratory Protection Directive [4] specifies which category of RPE is necessary for which type of work, depending on the risks. Additional training requirements and medical examination are required for several categories.

## 6.8 Smell/Odor

Many substances that may be present in the workplace have an odour that can be used to identify the substance in question, if they are present in a concentration that is perceptible, i.e. above the odour threshold. The odour threshold varies greatly from one fabric to another. Some substances can already be smelled in very low concentrations, while there are also substances that are not or hardly perceptible. In the latter case, it is possible for a person to be exposed to the substance without the worker being aware of it. In the case of highly hazardous substances, this can lead to dangerous situations. Carbon monoxide poisoning in stoves with a malfunctioning exhaust is a good example of this.

Odour thresholds and limit values are not linked. Odour is therefore not an indication of whether exposure is effectively controlled.

In practice, odour perception is used as a tool to signal that it is time to start using RPE or that the gas filter has blown out. However, this means that workers may be exposed to excessive concentrations if the odour threshold is higher than the limit value, or if a worker is unable to perceive the odour properly or at all. These are undesirable situations.

The choice of gas/vapour filters and the duration of use should be based on the expected concentrations, the performance of the filters and the conditions under which they are used. Based on these factors, it is determined when filters need to be replaced. Again, replacement should not be postponed until the smell indicates that a breakdown has occurred.

However, it is important to point out to employees the (im)possibility of odour recognition and the possible relationship between odour and concentration (risk), so that in unforeseen situations the odour of substances can be used as an additional factor to respond adequately to any dangers.

Annex C gives an overview of the odour thresholds of many different substances.

## 7 Nature of work in choice of RPE

It is important to consider the intensity of the work when selecting and using respiratory protective equipment (RPE). The air supply of the RPE must be carefully adjusted to the intensity of the work. Working hours are also a factor to be considered when choosing and using RPE. In addition, the aspects of communication, working alone and mobility are important. The influence of the nature of the work must be assessed in conjunction with the working conditions and in particular the climatic aspects (section 9.1).

### 7.1 Load

#### Inhalation resistance

If the worker draws in the air through a filter (in the case of non-powered filtering agents [see chapter 3]), the resulting resistance to inhalation must be overcome. This causes inconvenience. The exhalation resistance can also lead to discomfort. The heavier the work, the greater the nuisance. This nuisance can lead to the employee taking off the RPE out of breathlessness. For this reason, it is necessary to use an RPE with very low inhalation resistance or with an artificial air supply (powered filters or breathing apparatus) for heavy work. The supply of air also leads to an air flow along the face, which is often experienced as pleasant by the body during heavy work and the resulting heat emission, provided that the temperature of the air is not too low. On the other hand, a temperature of the supplied air that is too low can be perceived as a nuisance.

#### Air supply

The harder the work, the greater the amount of air the worker must inhale. This can result in the worker's need for air being greater than the air supply. This can cause respiratory distress, and the protection may be partially or completely lost. If the temperature is slightly exceeded, negative pressure will occur during inhalation, so that the protection is not completely lost, but can decrease considerably. In the event of a significant exceedance, polluted air from outside can be inhaled directly into the RPE (depending on the type of RPE) and it may be necessary for the employee to turn off the RPE due to respiratory distress. In practice, this can also lead to fainting or other health-related complaints.

The air supply of an RPE is usually given in litres per minute. To determine whether a given air supply is sufficient, it is necessary to determine what the air consumption is expected to be. This mainly concerns the maximum air flow (peak flow) during inhalation, as this determines the occurrence of negative pressure. An overview of loads and the associated ventilation is given in Table 8.1. In the standard NEN-ISO 16976-1 [60] the values of the maximum air flow (the peak flow) are shown in the unit l/sec. For the sake of readability in Table 8.1, the values in l/sec have been converted to l/min and rounded.

**Table 8.1:** Air supply required depending on load level [60, 61]

| Workload                 | Class | Activity description  | Airflow (l/min) |                             |
|--------------------------|-------|---|-----------------|-----------------------------|
|                          |       |   | Average         | Maximum (peak) <sup>4</sup> |
| Light to moderate weight | W1    | Seated work: <ul style="list-style-type: none"> <li>• Light handicrafts (writing, typing, drawing, sewing, bookkeeping)</li> <li>• Hand and arm activity (small hand tools, inspection, assembly or sorting of light objects)</li> <li>• Driving in a Vehicle</li> </ul> Standing Work: <ul style="list-style-type: none"> <li>• Drilling and milling (small parts)</li> <li>• Winding coils</li> </ul> | 30              | 125                         |
| Heavy to very heavy      | W2    | Intensive work with arms and the whole body: <ul style="list-style-type: none"> <li>• Carrying heavy equipment</li> <li>• Working with the sledgehammer</li> <li>• Working hardwood with a plane or chisel</li> <li>• Mowing by hand</li> <li>• Pushing or pulling heavily loaded handcarts or wheelbarrows</li> <li>• Breaking of castings</li> <li>• Laying concrete slabs</li> </ul>                 | 40              | 200                         |

<sup>4</sup> The peak value depends on the size of the person and whether they are talking. The above values refer to a person 1.88 m tall, 85 kg and non-talking. Talking increases the peak current considerably.

| Workload        | Class | Activity description   | Airflow (l/min) |                             |
|-----------------|-------|--|-----------------|-----------------------------|
|                 |       |  | Average         | Maximum (peak) <sup>4</sup> |
|                 |       | High-intensity activities at high to maximum speed: <ul style="list-style-type: none"> <li>Working with an axe</li> <li>Intensive shovelling or digging</li> <li>Climbing stairs, ramps or ladders</li> <li>Escape from mine or tunnel</li> <li>Walking fast with small steps</li> <li>Walking at a speed of more than 5.5 km/h</li> </ul>   |                 |                             |
| Extremely heavy | W3    | Continuous work for up to 5 minutes without breaks: <ul style="list-style-type: none"> <li>Rescue and firefighting work at maximum intensity</li> <li>Activities in which people in excellent physical and training condition exert themselves to 80% to 90% of their maximum physical work capacity</li> <li>Climbing stairs and ladders at high speed</li> <li>Rescue, recovery and transport of victims</li> <li>Walking at a speed of 5 km/h on a 20% slope</li> </ul> Work continuously for up to 15 minutes without breaks: <ul style="list-style-type: none"> <li>Intensive rescue and firefighting work</li> <li>Activities in which people in good physical condition and in good physical condition exert themselves to 70% to 80% of their maximum aerobic capacity</li> <li>Crawling and climbing through obstacles</li> <li>Debris removal</li> <li>Carrying a hose</li> <li>Walking at a speed of 5 km/h on a 15% slope</li> </ul> | 50              | 300                         |
| Up to 5 minutes | W4    | Continuous work for up to 5 minutes without breaks: <ul style="list-style-type: none"> <li>Rescue and firefighting work at maximum intensity</li> <li>Activities in which people in excellent physical and training condition exert themselves to 80% to 90% of their maximum physical work capacity</li> <li>Climbing stairs and ladders at high speed</li> <li>Rescue, recovery and transport of victims</li> <li>Walking at a speed of 5 km/h on a 20% slope</li> </ul>   | 65              | 365                         |

The peak values mentioned above apply to young, healthy individuals. Higher peaks are to be expected for older or less healthy employees.

In the case of RPE with fresh air supply (breathing apparatus), there is a choice between the way in which the amount of air can be supplied. A 'free flow' system is often used, where the flow rate can be set (and adjusted if necessary). A lot of air is used: the flow rates vary between 350 and 450 litres/min. Another supply system is the 'on demand' system. Air is only supplied when there is a breath. The flow rate depends on the amount of air exhaled. Less air is used: the flow rates are between 120 and 160 litres/min.

The air supply of the RPE will have to be sufficient to meet the peaks that may occur during the work to be carried out. In doing so, all activities must be assessed. In the case of light inspection work, for example, there is the possibility that the workplace can only be reached via a ladder. However, climbing a ladder falls into the category of very heavy work with peaks of up to 250 l/min. This is, for example, far above the minimum required air supply of a hood or helmet equipped with powered filtered air (120 l/min). It is therefore necessary to carefully weigh up the expected load and the required air supply against the air supply to be supplied by the RPE. In the case of heavy work, it is necessary to consider whether there are possibilities to make the work less arduous.

The risk of sucking in contaminated air from outside the RPE at high loads applies especially to RPE that are partially open, such as with a helmet and a hood. With devices that fit well to the face, such as full-face masks with an inner mask, the user can remain reasonably protected with a powered RPE, because the extra required air is inhaled through the filter. This does not apply to respirators, as no more air is available than the maximum that can be supplied. If this maximum is exceeded, the user will be forced to remove the mask due to respiratory distress.

Some of the RPE, the means of carrying the supply of breathing air or oxygen, are so heavy that the possibilities for carrying out additional work are limited. This places demands on the condition and health of the employee. The load can be limited by using lightweight materials.

### **Usage period**

In the case of heavy work, the maximum operating time of the filter used will be limited. The amount of air inhaled per minute is higher for heavy work than for moderate loads. Particle filters are more likely to close under heavy loads and are therefore more likely to cause high inhalation resistance, necessitating replacement. With gas filters, the operating time is shorter than with moderate load. This relationship is non-linear in many situations. The following aspects play a role in this:

- Breath minute volume;
- Properties of the substance;
- Temperature;
- Relative humidity.

An aid to this can be the use of calculation programs to calculate the maximum duration of use (see section 5.2.3). Chapters 3 and 4 provide more information about RPE and filter types.

## **7.2 Working hours**

Many RPEs involve a more or less strong load and are therefore a nuisance for the employee. The longer the use is, the nuisance will increase and breaks will have to be taken. This nuisance can be reduced by opting for RPE with a low weight and for devices that are less restrictive of visibility (due to the location and shape of the filter).

In the case of fresh air supply RPE (see Figure 4.2), the gas/air supply in cylinders must be considered. When using autonomous systems (SBCA) and recycled devices (CCBA), the supply of air is sufficient for a maximum of 15 to 110 minutes (depending on the size of the bottles and the load on the user). In the case of a long continuous period of use, we do not recommend the use of devices that press on the face (masks) and non-powered filtering devices (due to negative pressure). When using filters, they will blow (gases) or slam shut (dust) over time. This leads to a reduction in the protection of the RPE. To prevent this, a procedure must be established in the RP programme to ensure that the correct type (and capacity) of filter is used and that filters are replaced in a timely manner.

## **7.3 Communication**

In many employment situations, it is important that the employee can communicate verbally with colleagues. RPE such as half- or full-face masks can greatly impede that communication.

To improve the communication possibilities, protective equipment can be used which is equipped with a speech diaphragm or a microphone. Such a provision can also help reduce the feeling of being isolated from the environment. This feeling can arise in employees by wearing RPE.

## **7.4 Working alone**

If an employee performs his work alone, this can lead to serious situations in the event of refusal of the RPE or in the event of accidents. This is especially true in an atmosphere with a high level of exposure and especially if health effects can already occur during short-term exposure (exceeding STEL, Ceiling or IDLH values). In such a situation, the work must be carried out under supervision or in collaboration with one or more colleagues.

## **7.5 Mobility/ Freedom of movement**

Wearing RPE reduces the wearer's room to move. This ranges from a small reduction when wearing a filtering facepiece (where the half or full-face mask can be annoyingly in the field of vision) to a significant reduction in mobility when wearing Airline systems (SAR, where fresh air is supplied through hoses). The length of the hoses is the limiting factor. The worker has to pull the hoses along and they can get caught behind protrusions, or there can be a kink in them. Furthermore, the employee is bound by one route. Protrusions on the body, such as those used in RPE that are equipped with hoses or bottles (breathing air/oxygen), can also impede work or prevent passage through narrow openings, making the product less suitable as a form of RPE.

## 8 Working conditions when choosing RPE

It is necessary to consider the conditions under which the work is to be carried out when selecting and using respiratory protective equipment (RPE). The impact of working conditions, and particularly the climatic aspects, must be assessed in conjunction with the intensity of the work (section 8.1).

### 8.1 Heat stress

Wearing an RPE is always stressful for the employee. Especially when working under hot conditions, wearing RPE is an additional physical strain. In addition, wearing an RPE limits the body's ability to release the heat to the environment. Sweating can cause a mask to slide over the face, which reduces protection. Heat and shortness of breath can also cause the user of the RPE to take off the device for a moment to gasp for air or wipe their sweaty face.

When using filtering agents, it should be borne in mind that the filter also captures water vapour. As a result, the air coming out of the filter is drier and its temperature is higher than the temperature of the ambient air due to condensation heat. This can amount to a temperature increase of 5 to 10 °C.

Complaints about heat can occur with some RPE even at normal ambient temperatures. This happens more quickly when there is heavy work (greater physical exertion). It is therefore not a phenomenon that only occurs at extreme temperatures.

In a warm environment, masks with powered filtered air or respirators are preferable. The air that is blown past the face then has a cooling effect. If necessary, the air blown in must first be cooled. For cooling of air (when compressed air) is used, adiabatic decompression or the vortex principle can be used, which allows both cooling and heating. Information on cooling or heating air can be obtained from the suppliers of the RPE.

If, because of the combination of a warm environment, the intensity of the work and the protection to be worn, there is an excessive increase in the temperature of the body (heat load), regular breaks should be taken to limit the strain and allow it to cool down. In case of conditions leading to (strong) sweating, the use of masks is not recommended.

### 8.2 Cold, draughts

If the air temperature is too low, the risk of complaints is very high (especially at outside temperatures below 15 °C). This is often when eye complaints occur. The air can also be perceived as dry. If the air flow is too high, these symptoms are aggravated. Furthermore, the length of any air hoses plays a role and of course the heaviness of the work.

Employees who use an RPE with adjustable air supply tend to set the air supply as low as possible when the air supply is too cold. This can lead to a deterioration in the level of protection due to the occurrence of negative pressure. As a result, RPEs in which unheated ambient air is blown in can only be used to a limited extent under cold conditions or in the open air.

Very low temperatures can lead to freezing of exhaust valves or breathing apparatus components and to condensation. Then select an RPE that heats the supplied air. Also from the point of view of comfort, the air should be heated at low outside temperatures.

### 8.3 Moisture

Moist air can condense inside the mask, limiting the worker's vision. When using compressed air, the humidity can be so low that it can lead to complaints such as dry throat, nose and/or eyes, dehydration.

Condensation is more likely to occur during heavy work (sweat production) and at a low air temperature (which creates a higher relative humidity). Preventing condensation is important to avoid nuisance and to prevent the worker from turning off the RPE to clean the window. In situations with a

risk of condensation, RPE with air supply are preferable.

High relative humidity can also limit the useful life of filters. If necessary, another RPE should be selected.

## 8.4 Noise

If high noise levels occur in the working environment, the worker must also be protected against this. RPE and hearing protection equipment can interfere with each other (see also section 9.5). The RPE itself can also cause noise, for example by blowing in air. High noise levels can also occur when using a respirator in combination with a helmet during blasting work, due to grit or grit jumping against the helmet.

When selecting the right RPE, the combination with hearing protection equipment should also be considered, if applicable.

## 8.5 Combinations of different types of personal protective equipment

If several forms of personal protection are combined, they must be coordinated.

For example, the combination of a half-mask and corrective spectacles or safety glasses often leads to complaints because the glasses cannot be moved into the correct position. An alternative is a full-face mask with, if necessary, a frame attachment option. The use of a helmet or hood with a blower filter can also be considered.

The combination of a (not well-fitting) half mask and glasses can also lead to condensation on the glasses due to the blowing out of moist air along the edges of the mask.

Regular glasses will adversely affect the protection of a tight-fitting full-face mask. This can be solved by using a full-face mask in combination with goggles.

RPE's attachment straps may interfere with the operation of hearing protection. Wearing earplugs or otoplastics is therefore preferable to earmuffs, if this provides sufficient hearing protection.

The combination of a safety helmet and a full-face mask also generally does not work well. The straps of the RPE under the helmet deteriorate the protection provided by the helmet. In addition, the helmet often cannot be applied in the correct position, because the mask gets in the way. If RPE is to be combined with head protection, the choice of a helmet with a blower filter (powered air or breathing apparatus) is obvious, provided that the helmet complies with the guidelines for head protection.

Protective clothing that limits the emission of heat by the body in combination with an RPE can lead to heat load and impaired RPE functioning (see also sections 8.1 and 9.1).

Integrated protection is often more comfortable than combining different types of personal protective equipment. The individual components of the integrated protection, even if they are integrated into the overall system, must still meet the requirements.

## 9 Personal factors when choosing RPE

The most important personal factors influencing the wearing RPE are the health and condition of the worker, the shape of the head and the wearing of a beard, glasses or contact lenses. Diseases or health abnormalities can also cause limitations in the use of RPE.

Motivation and good training are also important for the correct use of the RPE (see chapter 2). If no or insufficient attention is paid to these personal factors, there is a good chance that the degree of protection achieved will be insufficient. There is also a chance that the use of RPE will lead to (exacerbation of) health effects. Among other things, Annex D of standard NEN-EN 529 contains extensive information about personal factors and their effect on the choice of RPE.

### 9.1 Condition, load capacity

The use of RPE can lead to a considerable (physical) strain for the employee. This must be considered in the choice of means and the selection of the workers who will be allowed to work with them.

In the case of workers who wear RPE regularly or for a long time, it must be determined by a specific medical examination whether this is justified (chapter 11). If wearing RPE can lead to problems due to the health condition of an employee or the expected load, choices will have to be made about the type of RPE to be worn and/or about the duration of use.

Certain RPEs, such as respirators that carry the supply of breathing air or oxygen, may be too heavy for some individuals to carry for an extended period. If other personal protective equipment or heavy equipment (tools) are to be used at the same time, the total load must be considered.

High temperatures in the workplace can make wearing RPE more likely to lead to problems (chapter 8). There can also be discomfort because an RPE creates an airflow on the face, which cools the skin. The wearer's skin can react (over)sensitively to direct contact between certain materials of the RPE and the skin.

Workers with limited lung function are more likely to experience problems when using dependent RPE (except for a motor-driven filter unit, PAPR).

### 9.2 Inhalation resistance

In the case of products without an artificial air supply, the inhalation resistance can lead to complaints of shortness of breath. The heavier the work and the greater the need for air, the more annoying the resistance will be and the more likely it will lead to complaints. The inhalation resistance is caused by the filter and is greatest with P3 filters and gas filters. When the particle filter is clogged and when there is a high need for breathing, the inhalation resistance increases sharply.

Another form of resistance that can lead to complaints is the exhalation resistance caused by the RPE. In the case of heavy work, filtering agents without a blower filter can only be used for a short period of time or occasionally, and devices with a blower filter or respirators should be chosen.

Tables 10.1 and 10.2 describe the maximum resistors of the filter and type of RPE. In practice, the maximum values are often lower. For each type of filter or RPE, these are recorded in technical datasheets of the products. These can be requested from the manufacturer or supplier.

**Table 10.1: Maximum filter resistance per filter type**

| Filter type                               | Class   | Maximum filter resistance according to EN standard |                   |
|---|---------|--|-------------------|
|   |         | @30 l/min in mbar                                  | @95 l/min in mbar |
| Particulate filters (NEN-EN 143:2000)     | P1      | 0,6  | 2,1               |
|   | P2      | 0,7  | 2,4               |
|   | P3      | 1,2  | 4,2               |
| Gas filters Type A, B, E and K (EN 14387) | GAS1    | 1,0  | 4,0               |
|   | GAS1-P1 | 1,6  | 6,1               |
|   | GAS1-P2 | 1,7  | 6,4               |
|   | GAS1-P3 | 2,2  | 8,2               |
|   | GAS2    | 1,4  | 5,6               |
|   | GAS2-P1 | 2,0  | 7,7               |
|   | GAS2-P2 | 2,1  | 8,0               |
|   | GAS2-P3 | 2,6  | 9,8               |
| Gas filters Type AX (EN 14387)            | AX      | 1,4  | 5,6               |
|   | AX-P1   | 2,0  | 7,7               |
|   | AX-P2   | 2,1  | 8,0               |
|   | AX-P3   | 2,6  | 9,8               |

**Table 10.2: Maximum filter resistance by type of respiratory protective device**

| Type of respiratory protection   |          | Maximum inhalation resistance according to EN standard |                                  | Maximum exhalation resistance according to EN standard |
|--|----------|--|----------------------------------|--|
|  |          | @30 l/min (in mbar)                                    | @95 l/min (in mbar)              |  |
| Filtering Face Piece (NEN-EN 149:2009)                                   | FFP1     | 0,6  | 2,1                              | 3.0 mbar @ 160 l/min                                   |
|  | FFP2     | 0,7  | 2,4                              |  |
|  | FFP3     | 1,0  | 3,0                              |  |
| Half mask with integrated filters and exhalation valve (NEN-EN 405:2009) | FFGAS1P1 | 6,1  | 1,6                              | 3.0 mbar @ 160 l/min                                   |
|  | FFGAS1P2 | 1,7  | 6,4                              |  |
|  | FFGAS1P3 | 2,0  | 7,0                              |  |
|  | FFGAS2P1 | 2,0  | 7,7                              |  |
|  | FFGAS2P2 | 2,1  | 8,0                              |  |
|  | FFGAS2P3 | 2,4  | 8,6                              |  |
|  | FFAXP1   | 2,0  | 7,7                              |  |
|  | FFAXP2   |  | 8,0                              |  |
| FFAXP3   | 2,4      | 8,6  |                                  |  |
| Half mask (NEN-EN140:1998)   |          | 0,5*   | 1,3*                             |  |
| Full face mask (NEN-EN 136:1998)   |          | ≤ 0.5*   | ≤ 1.5*<br>≤ 2.5 mbar @160 l/min* | ≤ 3.0 mbar @ 160 l/min                                 |

\*Without filters. See also the table of maximum filter resistances; These are in addition to the resistance of the mask body.

### 9.3 Concentration of carbon dioxide in the inhaled air

In almost all RPE, there is a space within the mask in which there is exhaled air that the user inhales again. This air contains carbon dioxide.

Inhaling exhaled air again leads to an increased concentration of carbon dioxide and can cause a feeling of tightness and headaches. The amount of exhaled air that is inhaled again depends on the space in the RPE: the dead (or empty) space. It should be as small as possible. The concentration of carbon dioxide can be reduced by a large flush with fresh air.

When testing RPE according to the various EN standards, the concentration of carbon dioxide in the dead space is measured. The average volume fraction of carbon dioxide in the inhaled air should not exceed 1%. There is one exception where a higher concentration of carbon dioxide is permitted: in the case of a motor-driven filter unit (PAPR) that is connected to a full or half mask (this is described in the standard NEN-EN 12942 [62]). In the event of a failure of the motor unit, the user inhales through the filter of the motor unit. Exhalation is then made through the mask. As a result, the dead space becomes larger, allowing a carbon dioxide concentration of 2%.

Compliance with these tests does not mean that health problems with the use of this RPE are excluded. To avoid an increased concentration of carbon dioxide, equipment that involves the injection of filtered air or breathing air is preferable to equipment that requires the worker to suck the air through a filter himself.

## 9.4 Diseases or health abnormalities

There may be health abnormalities or diseases that limit the use of RPE. Medical conditions that can influence the selection and use of RPE are, for example, respiratory infections, neurological problems (including epilepsy, ataxia (disturbance in movement and balance) or tremors (tremors)), psychological problems (depression or claustrophobia), impaired vision, hearing problems (including damage to the eardrum) or problems with balance (including vertigo or an ear infection).

Employees with a history of heart problems or severe lung disease are advised to consult with their treating physician or the company doctor before using RPE.

Workers with a temporary lung disease such as TB, pneumonia or bronchitis are advised to consult a physician before using RPE. Lung capacity may be reduced, or breathing may be impaired. As a result, the use of RPE may be impossible or the choice of RPE may be restricted. Sharing swimming equipment is not recommended, especially in case of health conditions.

Temporary respiratory problems such as colds, mild flu, hay fever or a runny nose may temporarily make it impossible to work with certain types of RPE. It may also be necessary to take extra breaks to make the work possible.

Psychological factors are also important. Employees may feel isolated or suffer from claustrophobia (the fear of being trapped or trapped). Wearing RPE can exacerbate these problems and greatly hinder the employee in the performance of the work or make it impossible to work. Training can be a way for some employees to get over mental health factors. In the case of psychological or neurological complaints, involve the individual employee and the company doctor in the choice of the RPE.

If communication is difficult, for example because of limitations in vision, field of vision, hearing and speech (see also chapter 8), employees may be tempted to turn off RPE. Communication can be improved by selecting RPE with effective voice transmitters and models with microphones or radios. These should be deployed when effective verbal communication is required to ensure the safety of workers and others.

Skin contact with RPE can lead to skin irritation. Employees can also be or become hypersensitive to certain types of plastic from which masks are made.

Selection of workers is acceptable only for special work. In principle, the choice of an RPE should be based on the health of the "average" worker. If, for personal reasons, a suitable type of RPE cannot be selected for an employee, the employee concerned will not be able to perform the work. The latter will have to be determined in consultation with a company doctor.

## 9.5 Shape of the face

The shape of the face affects the fit. For example, certain facial features may interfere with the fit of RPE, such as hollow temples, protruding cheekbones, deep skin folds, lip marks, the absence of teeth or use of dentures, facial injuries and swelling of the mouth or face.

It is therefore necessary to always select different types of RPE from which a choice can be made tailored to the individual. This may mean that you must choose RPE from different manufacturers. It is also important to make different formats available, if available.

If facial features prevent a good fit, you may also want to consider using a loose fit RPE, which does not rely on a tight fit.

Several studies have been carried out on the shape of the face over the years [63], [64], [65]. Among other things, these studies show that different anthropometric facial dimensions are possible between men and women, different ethnic groups or population groups, and different age groups.

## 9.6 Accessories

Accessories worn out of personal or religious conviction can influence the RPE to be worn. Think of a possible effect on the correct functioning or sealing of the RPE, but also possible problems when placing a lap belt or possible damage to accessories that can occur when removing the RPE.

Examples are cosmetics, gel, face jewellery or head covering. Accessories that affect the fit should be removed while wearing RPE. Also be aware of the effect of temples and accessories that may get in the way on the body, such as keychains or beepers.

## 9.7 Facial hair and hair

People with beards are limited in their choice of RPE. For these workers, a form of protection must be sought that does not allow leakage to occur. The types of RPE that depend on negative pressure for operation cannot be used. This applies not only to a fully grown beard but also to a stubble of a few days. Such hair often causes greater leakage compared to a full-grown beard. Studies have shown (NEN-EN 529) that even beard growth of less than a day can result in a significant increase in leakage of the RPE. Within the NEN-EN-529 it is advised not to shave a beard for more than 8 hours prior to a (shift) work. ISO 16975-3:2017 recommends shaving facial hair preferably 12 hours prior to a fit test.

Hair should be avoided from getting between the sealing surfaces of a tight-fitting RPE and the wearer's skin. Long hair can also interfere with the operation of an RPE (e.g. the operation of the valves). In case of hindrance from long or a lot of (head) hair, the use of a loose fit RPE can be considered.

## 9.8 Prescription glasses or contact lenses

The use of corrective glasses can interfere with the protection provided by many types of RPE. It is also possible that glasses cannot be applied in the correct position. When corrective glasses are required, they must have a design that is compatible with the RPE. If your own glasses cannot be used, it is possible to opt for so-called insert glasses. Insert goggles are specifically designed for use within the RPE without breaking the face seal. Mask goggles (goggles with temples) when using a tight-fitting mask are not recommended. If the use of glasses with temples is necessary, a 'loose fit' RPE should be chosen.

Contact lenses should only be used in combination with RPE by users who have had a wide, positive experience with contact lenses. It is recommended to have contact lens wearers practice wearing RPE beforehand to test whether a combination with lenses leads to problems. The use of contact lenses can lead to problems in certain situations. An airflow from an RPE in combination with contact lenses can lead to dry eyes and possibly irritation, tearing of soft lenses or loss of the lenses. In case of irritation, the wearer of the RPE will be tempted to remove the mask or cap to push or remove the contact lenses straight. The protection of the RPE will be lost, resulting in exposure. If there is a risk of deposition, the use of RPE in combination with contact lenses should not be recommended.

## 10 Face-fit tests

### 10.1 Introduction

The concept of face-fit testing of RPE is a growing phenomenon within various organizations. The standard NEN-ISO 16975-3:2017 (Fit-testing procedures) [66] describes the face-fit test as follows:

*Use of a challenge agent and specific protocol to qualitatively or quantitatively determine the effectiveness of the seal between the wearer's face and respiratory interface with a specific make, model, and size of a Respiratory Protective Device (RPD).*

In Australia, Canada, the United States and Great Britain, it is mandatory to subject employees to a face-fit test with their respiratory protection equipment once a year or once every two years.

In the Netherlands, too, the face-test is becoming increasingly mandatory, because it has been included in the Dutch Working Conditions legislation for the asbestos industry. In addition, face-fit testing is prescribed in various industries and for different applications. This is the case, for example, in the industrial cleaning sector, in the Chromium-6 management regime [67] and when working in contaminated soil (CROW 400 [59]).

There are many different types of face shapes and head sizes among employees. In addition, there are many types and sizes of RPE available. There is no 'one size fits all': without a face-fit test, not everyone uses the right, appropriate tool. With an RPE that does not fit properly on the face, there is a risk of exposure to hazardous substances. Especially with RPE in which a negative pressure is created during breathing, a poor fit causes inward leakage. Checking the fit of RPE with negative pressure by means of a face-fit test is therefore essential.

The face-fit test checks the close-fitting seal of a mask on the face. Face-fit tests can therefore only be taken by users of the so-called 'Tight Fitting' RPE: FFPs, half- and full-face masks. There is no face-fit test for 'Loose Fitting' RPE like fresh air hoods and helmets.

It is important that people who undergo a face fit test are clean-shaven and do not wear piercings in the sealing area. This means that there should be no stubble formation [68].

The standards EN 529 and NEN-ISO16975-3 standards indicate a maximum shaving time of eight and twelve hours respectively. The fit test protocols state that persons who do not meet the facial hair criteria should not be tested. A review study of facial hair and leakage at negative pressure RPE [69] shows that the protection can be reduced by a factor of 20 to 1000 in the presence of facial hair. This significant leakage is not visible in studies in independent RPE.

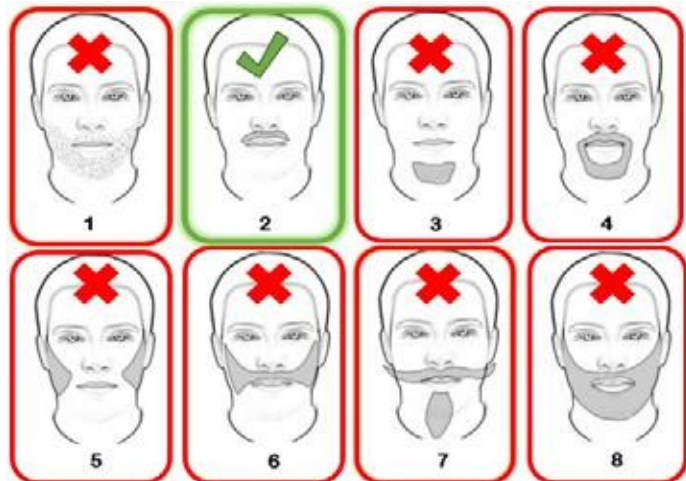


Figure 11.1: Example of permissible facial hair [96]

There are several reasons that can give rise to forms for (re)administering face-fit tests such as:

- Significant change in body weight, particularly weight loss ( $\geq 9$ kg) [70];
- Dental procedure;
- Surgery or scarring in the face;
- Experiencing discomfort while wearing;
- Experiencing leakage during use;
- As a training tool to create awareness among the user about their own influence on the correct use of the RPE.

## 10.2 Why face-fit testing?

Many studies [71] have shown that the protection provided by RPE in laboratory tests is not achieved in the workplace. The assigned protection factor (APF) has been established to give a more realistic value for the protection likely to be achieved in the workplace (see chapter 5). This value should be used when selecting adequate RPE. The APF is the level of respiratory protection at which it can realistically be expected to be achieved in the workplace by 95% of the adequately trained users monitored using properly functioning and correctly designed RPE. The assigned protection factor can therefore only be used reliably if it has been demonstrated by a face-fit test that the RPE shuts down sufficiently.

The American National Standard ANSI Z88.10 [72] states that the purpose of performing face-fit testing is to verify that the selected make, model and sizing is sufficiently suitable for a person's facial features, and that this provides assurance that the wearer can wear the RPE properly and achieve the expected protection during use.

The UK Respiratory Protection Working Group responsible for the issue of standard BS 4275 (which has been replaced by BSI EN 529) was more cautious and stated that face-cycling can only identify large leaks and cannot guarantee fit suitability. Passing a face-fit test does not guarantee that an adequate fit will be achieved every time a wearer uses an RPE. It identifies that a given RPE has the potential to provide an adequate fit, but to achieve this, the wearer must always use the mask correctly and check the fit by performing the fit t checks (seal check) as described in the manufacturer's user instructions.

Face-fit testing reflects the instantaneous application of the RPE to the user and is part of an effective RPE policy.

## 10.3 Methods of Face-fit tests

Face-fit tests can be divided into two main categories:

- Qualitative testing (QLFT) and
- Quantitative testing (QNFT).

In qualitative testing, leaks are observed by the user of the RPE. In quantitative tests, leakage is detected by means of special measuring equipment. Table 11.1 shows which method of face-cycling is suitable for each type of RPE.

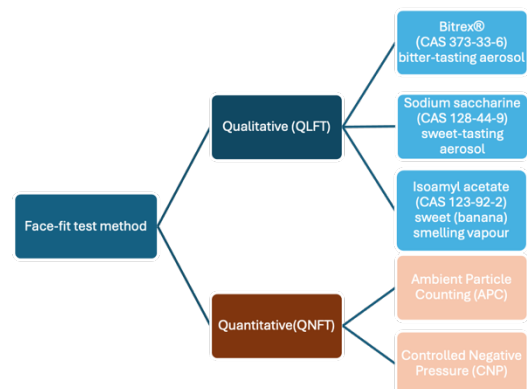


Figure 11.1: Overview of face-fit methods

Table 11.1: Comparison of methods and protocols face-fit test

| Mask Type                                      | Fit Test Method     |      |                    |
|--|---------------------|------|--------------------|
|  | Quantitative (QNFT) |      | Qualitative (QLFT) |
|  | APC                 | CNP* | Taste              |
| <i>Disposable:</i>                             |                     |      |                    |
| FFP (NEN-EN 149)                               | Yes                 | No   | Yes                |
| <i>Reusable:</i>                               |                     |      |                    |
| Half mask (NEN-EN 140)                         | Yes                 | Yes  | Yes                |
| Half mask with integrated filters (NEN-EN 405) | Yes                 | No   | No**               |
| Full face mask (NEN-EN 136)                    | Yes                 | Yes  | No                 |
| <i>PAPR (motor-driven filter unit):</i>        |                     |      |                    |
| Half mask (NEN-EN 12942)                       | Yes                 | Yes  | Yes                |
| Full face mask (NEN-EN 12942)                  | Yes                 | Yes  | No                 |
| <i>Constant flow airline:</i>                  |                     |      |                    |
| Half mask (NEN-EN 14593-2)                     | Yes                 | Yes  | Yes                |

|                                 |     |     |     |
|---------------------------------|-----|-----|-----|
| Full face mask (NEN-EN 14593-1) | Yes | Yes | Yes |
|---------------------------------|-----|-----|-----|

| Mask Type                   | Fit Test Method     |      |                    |
|-----------------------------|---------------------|------|--------------------|
|                             | Quantitative (QNFT) |      | Qualitative (QLFT) |
|                             | APC                 | CNP* | Taste              |
| <i>Breathing apparatus:</i> |                     |      |                    |
| Full face mask (NEN-EN 137) | Yes                 | Yes  | No                 |
| <i>EEBD Escape set:</i>     |                     |      |                    |
| Full face mask (NEN-EN 402) | Yes                 | Yes  | No                 |

APC = Ambient Particle Counter = particle test  
 CNP = Controlled Negative Pressure = negative pressure test  
 \* options are subject to availability of adapters  
 \*\* only possible with type A filter with isoamyl acetate vapour

### 10.3.1 Qualitative face-fit test

The qualitative face-fit test is described in the standard NEN-ISO16975-3 (Fit-testing procedures) as follows:

*Pass/fail test method that relies on the subject's sensory response to detect a challenge agent in order to assess the adequacy of RPD fit.*

The qualitative face-fit test is a subjective testing method. In this test, the user must put on their RPE and then gets a hood over their head. In this hood, a bitter (Bitrex®) or sweet substance (saccharin) is atomized (aerosol) that can be tasted.

If a half mask with an A filter (organic substances with a boiling point >65°C) is tested, isoamyl acetate vapour must be used, which can be smelled. The test substance isoamyl acetate is not suitable for particle filters such as FFPs and P2/P3 filters.

Before starting to carry out the qualitative face-fit test, a safety test, which determines the degree of nebulization during the face-fit test.



**Figure 11.2:** Qualitative face-fit test

If, in the sensitivity test, the person to be tested is unable to perceive the bitter or sweet mist/vapour, then this test method is not suitable. This test is administered using a fit test protocol as described in the OSHA protocols [73] or the standard NEN-ISO 16975-3.

When taking the sample, the qualitative fit factor is determined. The standard NEN-ISO 16975-3 describes this as follows:

*Qualitative estimate of the minimum fit of a particular tight-fitting RPD to a specific individual when a qualitative fit test is passed, i.e. the test agent is not detected by the subject's senses.*

This test method is only suitable for FFPs and half masks up to a fit factor of 100 (see 11.4 for more information on the fit factor). However, the test method is error-prone due to the number of operations and control points. Depending on the type of nebulizer, these tests are very intensive for the person performing the face-fit tests (fit tester). If possible, the working group recommends opting for a quantitative face-fit test method.

### 10.3.2 Quantitative face-fit test

The quantitative face-fit test is described in the standard NEN-ISO16975-3 (Fit-testing procedures) as follows:

*Test method that uses an instrument to assess (quantify) the amount of face-seal leakage into the RPD in order to assess the adequacy of its fit.*

The quantitative face-fit test is a (more) objective way to check the sealing of the RPE at the employee's premises. To perform a quantitative face-fit test, a fit-test protocol must be followed. Each face-fit test protocol consists of several exercises that the wearer of the RPE must go through. During the face-fit test, a quantitative fit factor (QNFF) is calculated for each exercise. The standard NEN-ISO 16975-3 describes this as follows:

*Numeric value of the fit of a particular tight-fitting respiratory interface to a specific individual.*

**Note:** It represents only respiratory interface to face leakage. Leakage from other sources (e.g. air purifying elements, exhalation valve) should be significantly lower than the measured face-seal leakage. The QNFF is measured with specialized instrumentation.

Each face-fit test protocol has a set minimum required fit factor. The NEN-ISO 16975-3 standard describes these as follows:

*Numeric value established as a pass/fail point or acceptance criterion for quantitative fit testing.*

If the result of the measurement is higher than the established minimum required fit factor, a 'pass' will be given. The minimum required fit factors vary per protocol in terms of values and calculation method.

Although not well documented, the accepted practice in the United States is to use  $\geq 10x$  the APF value as the Fit Factor Pass Level for quantitative face-fit testing [74].

Two methods of quantitative face-fit testing are distinguished: the particle test (Ambient Particle Counter; APC) and the Controlled Negative Pressure test (CNP).

#### *Ambient Particle Counter (APC) / Particle Test*

This type of technology is also referred to as "ambient aerosol condensation nuclei-counting" (CNC). These measuring instruments can measure particles of a specific size in air (the measuring range of the widely used PortaCount TSI is between 0.02 and 1.0  $\mu\text{m}$ ). When performing the face-fit test, the particle concentration is measured around the head ( $C_{\text{out}}$ ) and the particle concentration in the breathing zone of the RPE ( $C_{\text{in}}$ ) at the time that prescribed movements from the face-fit test protocol are performed.

Based on this, a fit factor is calculated for each exercise by dividing  $C_{\text{out}}$  by  $C_{\text{in}}$  ( $\text{FF} = C_{\text{out}}/C_{\text{in}}$ ).

Particles are naturally present in the environment that are within the measurement range of the APC equipment. However, this concentration may be too low to make a reliable measurement. This is particularly the case for large rooms, rooms with a high ventilation, clean workstations or clean room environments.

To generate particles, a particle generator (sodium chloride aerosol) can be used, or some candles can be safely burned.

The APC is not able to distinguish between exhaled particles, seal leaks, valve leaks and filter leaks. Leakage from sources other than seal leakage can result in (very) low fit factors. To rule out these factors, it is important to:

- Only use well-maintained and tested RPE.



**Figure 11.3:** Quantitative face-fit test



**Figure 11.4:** FitPro Ultra software TSI PortaCount

- Use filters that effectively block the aerosol to be measured (P3 or P100<sup>5</sup>);
- Create a stable concentration of particles around the test subject. See the principles as described by the manufacturers of APC equipment.
- Consider exhaled particles, such as particles exhaled after smoking a cigarette. Therefore, it is advised to wait 30-60 minutes before taking the face-fit test after smoking a cigarette. The influence of exhaled particles is often visible during the test step 'speaking' of the fit-test protocol. Finally, it is important that the person to be tested does not speak with 'consumption'.



**Figure 11.5:** Full face mask with Rd 40mm (CEN) test adapter and P3 filter



**Figure 11.6:** FFP with probe

In order to be able to perform face-fit tests, masks are provided with an adapter with a piece of measuring tube that is placed in front of the mouth. The suppliers of APC equipment offer various adapters for various brands and connections. If it is not possible to connect an adapter, as is the case with FFP masks, the mask can be fitted with a measuring connection by means of a probe in the mask body. After applying the probe and taking the measurement, it is no longer possible to use the mask as an RPE.

#### *Controlled Negative Pressure (CNP) / Negative pressure test*

During the performance of a face-fit test, a negative internal pressure is created in the RPE (challenge pressure; CP) which simulates a range of work activities (work rates). This is called the inspiratory flow rate (IFR). The primary factors influencing the negative pressure in a mask during inhalation are the work activities and the filter resistance. The CNP method is based on exhaling air into a sealed half- or full-face mask when it is put on correctly. In this process, the measuring device generates and maintains a constant negative pressure in the mask. The speed of the air extraction is controlled in such a way that a constant negative pressure in the respirator is maintained during the face-fit test. When the pressure in the facepiece is constant, the airflow from the facepiece is equal to the air leaking into the facepiece, i.e. the leakage of the facepiece. This is called the leakage flow rate (LFR). Therefore, measuring the exhaust air required to keep the pressure in the temporarily sealed mask constant provides a direct measurement of the airflow leaking into the facepiece. A CNP fit factor is calculated from the ratio of the inspiratory flow rate (IFR) to the measured leakage flow rate (LFR).  $FF = IFR / LFR$ . Table 11.2 below describes the test conditions for the various fit test protocols.



**Figure 11.7:** Quantifit 2

<sup>5</sup> P100 filters are supplied as standard by the suppliers of APC equipment (these come from USA). a direct measurement of the airflow leaking into the facepiece. A CNP fit factor is calculated from the ratio between the inspiratory flow rate (IFR) and the measured leakage flow rate (LFR).  $FF = IFR / LFR$ . Table 11.2 below describes the test conditions for the different fit test protocols.

**Table 11.2: CNP equipment settings according to fit test protocols**

|                             | Fit Test Protocol |              |             |
|-----------------------------|-------------------|--------------|-------------|
|                             | OSHA 1910.134     | HSE INDG 479 | ISO 16975-3 |
| <i>Half mask</i>            |                   |              |             |
| Inspiratory flow rate (IFR) | 53.8 L/min        | 53.8 L/min   | 53,8 L/min  |
| Challenge pressure (CP)     | -1.5 mbar         | -1.5 mbar    | -1,45 mbar  |
| <i>Full Face Mask</i>       |                   |              |             |
| Inspiratory flow rate (IFR) | 53.8 L/min        | 53.8 L/min   | 53,8 L/min  |
| Challenge pressure (CP)     | -1.5 mbar         | -2.5 mbar    | -1,45 mbar  |

The CNP face-fit test assumes that the volume of air in the facepiece is constant during the test, which means that the fit factors cannot be measured while performing movements or while the wearer is breathing. Instead, fit is measured at the end of each fit test exercise while the wearer is standing still and holding their breath.

#### *APC versus CNP*

The technical difference between the APC and CNP method is the use of the measuring medium. In the case of APC, these are particles in the environment and in the case of the CNP, it is the ambient air (gas). Research into fit test procedures for RPE with a gas/vapour filter shows that leakage for both sodium chloride (NaCl, aerosol) and sulphur hexaboride (SF6, gas) give similar results when used to perform a face-fit test [75].

In addition to the technical differences, there is a substantial difference in the time of measurement between these two methods. With the APC test, measurements are taken while performing the movements (dynamic measurement). With the CNP test, measurements are taken after performing the movements; stationary with the breath held (static measurement). Research into different face-fit test methods shows that the APC method shows a strong correlation with the measured exposure under laboratory conditions [76]. The CNP method indicates a weak correlation. This study suggests that some quantitative methods (including APC) can be used to estimate the actual performance of RPE under laboratory conditions [77].

#### **10.3.3 Face Fit Testing Protocols**

Internationally, various protocols for face-fit testing have been described. In the Netherlands, the following protocols are used:

- USA [73] OSHA 1910.134
- UK [78] HSE INDG-479
- International [66] ISO 16975-3

Within the petrochemical sector, the OSHA protocol is often used. This protocol is often prescribed in the company's policy on RPE use.

Each protocol has requirements for each measurement method (preparations for collection, procedure for carrying out the face-fit test, determination of the measurement results, etc.). Within the protocols, there is variation in the type of subtests and during or after performing these tests. The choice of the fit test protocol depends on legislation, industry (Working Conditions Catalogue) or company regulations. Table 11.3 compares the fit test protocols using the ambient particle counting method (APC).

**Table 11.3: Comparison of face-fit test protocols APC**

|  | OSHA 1910.134  |                                   |                             | HSE INDG 479                                       | ISO 16975-3   |
|--|--|-----------------------------------|-----------------------------|--|---|
|  | OSHA Standard Protocol   | OSHA-Fast half/full mask protocol | OSHA-Fast FFP mask protocol |  |   |
| <b>Comfort assessment period before the fit test</b> | 5 minutes  | 5 minutes                         | 5 minutes                   | 5 minutes  | 5 minutes   |
| <b>Facial hair</b>                                   | No facial hair is allowed within the seal area, such as stubble, beard, moustache, or sideburns. |                                   |                             | Clean-shaven max. 8 hours before the start of work | Clean-shaven max. 12 hours before the start of work |
| <b>Number of test exercises</b>                      | 8  | 4                                 | 4                           | 7  | 7   |

|   | OSHA 1910.134   |  |  | HSE INDG 479   | ISO 16975-3  |
|---|---|--|--|--|--|
|   | OSHA Standard Protocol  | OSHA-Fast half/full mask protocol                                | OSHA-Fast FFP mask protocol                                      |  |  |
| <b>Activity during test exercises</b>                           | Normal breathing<br>Deep breathing<br>Head side to side<br>Head up and down<br>Talking<br>Smiling<br>Bending over<br>Normal breathing again | Bending over<br>Jogging<br>Head side to side<br>Head up and down | Bending over<br>Talking<br>Head side to side<br>Head up and down | Normal breathing *<br>Deep breathing<br>Head side to side<br>Head up and down<br>Talking<br>Bending over<br>Normal breathing again | Normal breathing<br>Deep breathing<br>Head side to side<br>Head up and down<br>Talking<br>Bending over<br>Normal breathing again |
| <b>Fit Factor pass level</b>                                    | FFP: 100<br>Half-mask: 100<br>Full-face mask: 500   | FFP: 100<br>Half-mask: 100<br>Full-face mask: 500                | FFP: 100<br>Half-mask: 100<br>Full-face mask: 500                | FFP: 100<br>Half-mask: 100<br>Full-face mask: 2000   | FFP: 100<br>Half-mask: 100<br>Full-face mask: 2000   |
| <b>Calculation method of 'pass' criterion for face fit test</b> | Average value of all exercises  | Average value of all exercises                                   | Average value of all exercises                                   | All individual exercises must $\geq$ pass level  | Average value of all exercises   |
| <b>Total test cycle duration</b>                                | 7 min 15 sec  | 2 min 29 sec   | 2 min 29 sec   | 7 minutes  | 7 min 15 sec   |
| <b>Standard time per face-fit test **</b>                       | 20 minutes per test   | 15 minutes per test  | 15 minutes per test  | 20 minutes per test  | 20 minutes per test  |
| <b>Fit test frequency</b>                                       | Annually  | Annually   | Annually   | At least once every 2 years ***  | Annually   |

\* During the performance of all activities (except for the exercise "bending forward") you will cycle, cycle on an exercise bike, walk on a treadmill, or perform walking movements (step-up).

\*\* The standard time is given for the purpose of planning face-fit testing. This is made up of: explanation and instruction 3 min, comfort period 5 min, time and completion 3 min.

\*\*\* The Dutch Working Conditions legislation stipulates that face-fit tests in the asbestos sector must be taken annually for each type of respiratory protection device [79] [57].

Table 11.4 compares the protocols for face-fit testing using the controlled negative pressure (CNP) method.

**Table 11.4: Comparison of face-fittest protocols CNP**

|   | OSHA 1910.134   |   | HSE INDG 479  | ISO 16975-3   |
|---|---|---|---|---|
|   | OSHA Standard Protocol  | OSHA-redon protocol *   |   | ISO redon protocol  |
| <b>Comfort assessment period for the fittest</b>        | 5 minutes   | 5 minutes   | 5 minutes   | 5 minutes   |
| <b>Facial hair</b>                                      | No facial hair is allowed within the contours of the seal, such as stubble, beard, moustache or sideburns.                                |   | Clean-shaven max. 8 hours before the start of work  | Clean-shaven max. 12 hours before the start of work   |
| <b>Number of sub-tests</b>                              | 8   | 5   | 7   | 5   |
| <b>Activity during sub-tests</b>                        | Normal breathing<br>Deep breathing<br>Head back and forth<br>Head up and down<br>Talking<br>Smiling<br>Bending over<br>Breathing normally | Looking Ahead<br>Bending<br>Head Shake<br>Head To Sides<br>Mask redon 1<br>Mask redon 2<br>Bending Forward<br>Head back and forth<br>Mask Redon 1<br>Mask Redon 2 | Breathing<br>Normally Breathing<br>Deep Breathing<br>Head Moving from Sides<br>Head Up and Down<br>Talking<br>Bending Forward<br>Breathing Normally | Looking ahead<br>Bending over<br>Shaking head from side to side<br>Mask redon 1<br>Mask redon 2 |
| <b>Fit Factor pass level</b>                            | Half mask: 100<br>Full face mask: 500   |   | Half mask: 100<br>Full face mask: 2000  | Half mask: 100<br>Half mask: 500  |
|   | Half mask: 100  |   |   |   |
| <b>Calculation method 'pass' criterion face-fittest</b> | Average value of all subtests   | Average value of all subtests   | All individual subtests must be the $\geq$ pass level   | Average value of all subtests   |
| <b>Total Measurement Cycle Time Duration</b>            | 7 min 15 sec  | 3 minutes   | 7 minutes   | 3 minutes   |

|                                      | OSHA 1910.134          |                       | HSE INDG 479                  | ISO 16975-3         |
|--------------------------------------|------------------------|-----------------------|-------------------------------|---------------------|
|                                      | OSHA Standard Protocol | OSHA-redon protocol * |                               | ISO redon protocol  |
| <b>Standard time face-fittest **</b> | 20 minutes per test    | 15 minutes per test   | 20 minutes per test           | 15 minutes per test |
| <b>Fittest frequency</b>             | Yearly                 | Yearly                | At least 1x every 2 years *** | Yearly              |

\* Redon: the RPE is turned off and put back on.

\*\* The standard time is given for the purpose of scheduling face-fit tests. This is made up of: explanation and instruction 3 min, comfort period 5 min, time and completion 3 min.

\*\*\* The Dutch Working Conditions legislation stipulates that face-fit tests in the asbestos sector must be taken annually for each type of respiratory protection device [79] [57].

## 10.4 Fit factors and protection factors

Fit factors (FF) obtained by performing face fit tests should not be confused with Work-place Protection Factors (WPF) or Assigned Protection Factors (APF). Several WPF studies consistently show that there is no correlation between quantitative fit factors (FF) and workplace protection factors (WPF) [80].

When calculating the theoretical exposure of a person to a hazardous substance, the APF should be used and not the Fit Factor. For example, if the measured fit factor is 5000 and an RPE is used with an APF of 10, 1/10 of the ambient concentration should be used as the exposure level and not 1/5000. The face-fit test was performed in a simulation of movements during work and not an actual measurement under working conditions. The Fit Factor should never be used as a Workplace Protection Factor (WPF) or Assigned Protection Factor (APF).

The fit factor should only be used as a pass/fail criterion to determine whether the fit is sufficient for the person concerned.

## 10.5 Frequency of face-fit testing

For the Dutch asbestos sector [79] [57], it is laid down by law that the face-fit test must take place annually. Within the industrial sector, other periods of two or three years are also used [81]. An important variable that has a major influence on the proper connection and protection of the RPE is the user himself. Particularly in dependent RPE, the general perception is that little attention is paid to the practical training of the use, even though this is one of the most crucial variables. A face-fit test can serve as a training tool to make the effect of the use of RPE immediately visible.

The **respiratory protection working group of the NVvA** recommends conducting the face-fit test once per year for all types of dependent RPE that fit closely to the face ('tight fitting'). Under the following conditions, this frequency may be reduced to once every two years or once every three years:

- Ensure that there is an adequate training program for all types of RPE in use. Pay attention to practical training on the correct use of the RPE. Establish a refresher training frequency.
- Ensure there is supervision of the timely and correct use of RPE.
- Ensure that no obstructive facial hair or jewellery is present while using RPE.
- Ensure that RPE is maintained after use in accordance with the manufacturer's instructions. Pay particular attention to the replacement intervals of valves.
- Only reduce the frequency if the minimum fit factor pass criterion is met in each subtest.
- Annually ask each person the following questions (to be answered with Yes or No). The response is linked to the actions of whether or not to invite for a face-fit test.

| Question  | Answer = YES           | Answer = NO            |
|---|------------------------|------------------------|
| 1. Do you experience leakage when using the RPE?                                  | Invite to face-fittest | No action              |
| 2. Are you clean-shaven (no stubble) when using RPE?                              | No action              | Invite to face-fittest |
| 3. Have you had it applied to the face in the past year, such as a piercing?      | Invite to face-fittest | No action              |
| 4. Have you had a dental procedure that has had teeth removed or dentures placed? | Invite to face-fittest | No action              |

| Question  | Answer = YES           | Answer = NO            |
|---|------------------------|------------------------|
| 5. Has your weight decreased or increased by 9 kg in the past year?   | Invite to face-fittest | No action              |
| 6. Has there been a skin change (lipping, wrinkling or folding) or medical intervention on the face in the past | Invite to face-fittest | No action              |
| 7. Do you know how to set up the RPE in accordance with the instructions for use and how to perform a leak      | No action              | Invite to face-fittest |

## 10.6 Simultaneous execution of face-fit tests

The British organisation Fit2Fit (<https://www.fit2fit.org>) has conducted research into the simultaneous performance of face-fit tests on several people [82]. Simultaneous execution of qualitative tests is not recommended. Simultaneous testing in quantitative testing is only recommended for the APC method if it is performed by an experienced fit tester with up to two devices. With three or four devices, two experienced fit testers are needed.

## 10.7 Infection prevention when performing face fit testing

During the Covid-19 pandemic (2020-2022), more attention has been paid to infection prevention when performing face-fit tests. Before the outbreak of the Covid pandemic, the reuse of masks for face-fit testing was a common occurrence. After the test, the mask was cleaned with a disinfectant wipe and reused for the next person who had to undergo the face-fit test. To prevent the risk of spreading viruses, this method is not suitable.

The following measures are recommended and are aimed at preventing and minimizing the risk of infection during the performance of face-fit testing:

- Evaluate the infection risks on the basis of the current situation and advice from the RIVM.
- Follow the current infection prevention measures of the RIVM and the company regulations.
- Use a wrapped, clean and disinfected mask for each person.
- Disinfect the mask adapter before and after the test. In the case of full-face masks, the piece of measuring tube on the inside must be removed and disposed of (only with the APC method).
- Use a new P3 filter for each person (APC method only) and full and half masks.
- Clearly separate unused and used masks.
- The fit-test operator wears latex or nitrile gloves that are frequently replaced. Depending on the current situation, a medical mouth or FFP2/3 mask can be worn by the face-fit tester.
- Disinfect hands and work surfaces regularly.

## 10.8 The Yellow Safety Sign Mark

Face-fit tests are administered by a fit tester. The people who take a face-fit test must be competent. The measurement method used must be validated and the measuring equipment used must be maintained and calibrated on time. To demonstrate that a supplier complies with this, there is the yellow Safety Sign quality mark of the Safety Sign Foundation. For the asbestos sector, it is laid down by law that a face-fit test must be taken by a Yellow Safety Sign-certified company and person [79] [57].



The company certifications can be consulted via the website of the Safety Sign Foundation (<https://safetysign.nl/>) and the register of recognized face-fit testers can be consulted via the website of the CEC Institute (<https://www.instituutcec.nl/face-fitteste/>).

## 10.9 Advice working group NVvA

The NVvA working group advises the following:

- Preferably choose quantitative face-fit tests.
- Perform a face-fit test on all types of close-fitting dependent respiratory protection (RPE filter).
- Use the OSHA 1910.134 Fast of Redon protocol for dependent respiratory protection as a basis.

Justification:

- FFPs and half masks have a minimum required fit factor of 100 in all protocols.
- Full face masks vary by protocol in the minimum required fit factor. If the APF-UK values for dependent RPE are used, then the minimum required fit factor of OSHA 1910.134 protocol meets the criterion of  $\geq 10x$  APF for full face masks. Other protocols, such as the HSE INDG 479 and ISO 16975-3 protocols, also comply with this, but do not have a shortened protocol for both QNFT techniques (APC and CNP).
- If a higher APF value is assigned to dependent RPE than the APF-UK values, it is recommended to opt for the HSE INDG 479 protocol.
- Use the HSE INDG 479 protocol for RPE used in asbestos removal. This is a legal obligation.
- Repeat the face-fit test annually or under the previously described conditions at least once every 3 years.
- Fit tests performed according to other fit testing protocols may be equivalent and used in the following manner:

|                          | Face-fittest according to protocol |               |                              |
|--------------------------|------------------------------------|---------------|------------------------------|
|                          | OSHA 1910.134                      | ISO 16975-3   | HSE INDG 479                 |
| Equivalent and valid for | -                                  | OSHA 1910.134 | OSHA 1910.134<br>ISO 16975-3 |

- Preferably use companies that are Yellow Safety Sign certified to carry out face-fit tests.
- When performing face-fit tests, make an inventory of the current infection risks and take appropriate measures.

## 11 Occupational health guidance

The use of respiratory protective equipment (RPE) can lead to a considerable (physical) strain on the worker. This must be considered in the choice of resources and the selection of the workers who will be allowed to work with them. This may mean that the use of occupational health counselling is necessary.

### 11.1 Dutch laws and regulations

There are no unambiguous laws and regulations on possible mandatory medical examinations during activities in which RPE is used. In the "Guidelines for mandatory medical examinations of employees during their employment" [83], the NVAB has listed the information about medical examinations. The guideline discusses medical examinations during employment. The guideline indicates that knowledge about the purpose and content of mandatory medical examinations is not easily accessible and that the scientific basis for many medical examinations is lacking. The guidelines indicate that some of the requirements for medical examinations are included in category laws and regulations, such as for fire brigade personnel (in Article 4 of the Decree on the Personnel of Safety Regions [84]). Various Collective Labour Agreements (CAO) also include agreements on medical examinations (e.g. in the Collective Labour Agreement for Construction & Infra [85]).

Working with RPE can result in a special job requirement, where there is an increased risk of affecting the health and/or safety of the employee.

In addition to a medical examination during employment, there may also be a medical examination prior to employment. In this case, we are talking about appointment examinations. More information about appointment examinations can be found in the "Guidelines for appointment examinations" of the NVAB [86]. An appointment examination must be distinguished from the so-called entry examination. An entry examination takes place after the appointment and has the purpose of determining the initial situation, getting to know the company doctor, the possibility of providing information, etc.

The most important regulations relating to the appointment examination can be found in the Medical Examinations Act (WMK [87]) and in the accompanying Decree on Appointment Examinations [88]. Appointment examinations may only be carried out if there are special job requirements within the position that impose special requirements with regard to the medical fitness of the employee (special load capacity requirements). This is to protect the health and safety of the inspector. When wearing RPE, there may be special job requirements.

In 2013, the NVAB defined the PME in the "Guidelines for Preventive Medical Examination (PME) for Workers" [89] as "a medical examination that is offered and carried out in a commercial manner without a client having a concrete health complaint or an indication for a health risk or problem. The purpose of the PME is to identify, prevent or treat this risk or problem at an early stage, or to be able to offer a client other options for action."

Article 18 of the Working Conditions Act, and various provisions of the Working Conditions Decree describe the legislation behind the voluntary periodic occupational health examination (PAGO) referred to here. Wearing RPE is often not a subject within the PAGO, because it is already included in the inspections described above.

### 11.2 Practical examples of inspections and research in relation to RPE

With a few practical examples, this section sketches a picture of the practice surrounding examinations or medical research in relation to RPE. This is not a complete overview. It is recommended to always consult with the company doctor in advance prior to any scheduling or carrying out of an examination. The frequency of execution should also be discussed with the company doctor.

*Collective Labour Agreement for Construction & Infrastructure*

Volandis has made agreements with various occupational health and safety services about the

implementation of the collective labour agreement package for individual preventive care [90]. These agreements are periodically adjusted.

In the various collective labour agreements in the construction sector, employees working in positions with special health risks are entitled to a Targeted Periodic Examination (TPE). The explanatory notes to the TPE 'Working in or with contaminated soil and/or groundwater', the TPE 'Asbestos' and the TPE 'Working on sites of the chemical industry' state that for special projects involving work in liquid- and/or gas-tight suits in combination with breath-independent respiratory protection (breathing air via hoses) it may be necessary to supplement the TPE with an exercise physiological study (minimum requirement 40 ml/kg/min. aerobic ability, similar to repressive fire brigade personnel). The CROW-400 [59] refers to the occupational health examination with this supplement as the C-examination.

For working with breathing air, a TPE is defined as "working with compressed air". Working with breathing air falls under physically demanding working conditions. A specific medical examination is necessary to determine suitability for that work. Components of this medical examination include a lung function test and an exercise physiological examination (bicycle or treadmill ergometry).

In most cases, the frequency of output is determined by the age of an employee at a TPE.

#### *Working Conditions Catalogue for the Waste Industry*

In 2023, the Working Conditions Catalogue for the Waste Industry indicated that the obligation to participate in a medical examination is required to wear RPE [91]. The inspection is subject to a frequency based on age (<40 years = once every four years; 40-50 years = once every two years; >50 years = once a year).

#### *Respiratory Protection Handbook for the Industrial Cleaning Sector (SIR)*

The handbook Respiratory Protection of the SIR [4] states that users of a full-face mask (SIR class A) and users of self-contained respiratory protection (SIR class B) must have a medical examination performed. The employer is held responsible for this. The user of RPE in SIR Class C must have a medical examination performed and a load/ergometry test or similar test.

For classes B and C, the following frequency is recommended: <40 years at least once every three years; 40-50 years at least once every two years; >50 years at least once a year.

#### *CROW 400 (working in and with contaminated soil)*

The classification in a safety class (6 pieces) from CROW-400 [59] is based on:

- the content of the contaminants present,
- whether they are volatile or non-volatile substances.
- the presence or absence of adequate ventilation (in the case of volatile substances
- and the presence or absence of carcinogenic or mutagenic substances (including asbestos).

According to CROW-400, participation in a medical examination is mandatory if employees in the safety class must work in red or black. Employees must then be inspected annually. They also have a certificate of suitability (pass). More information about the requirements can be found in module 7 of the CROW-400. A special inspection is required for the use of so-called workplace air-independent RPE (See CROW-400, module 7, table M7.1).

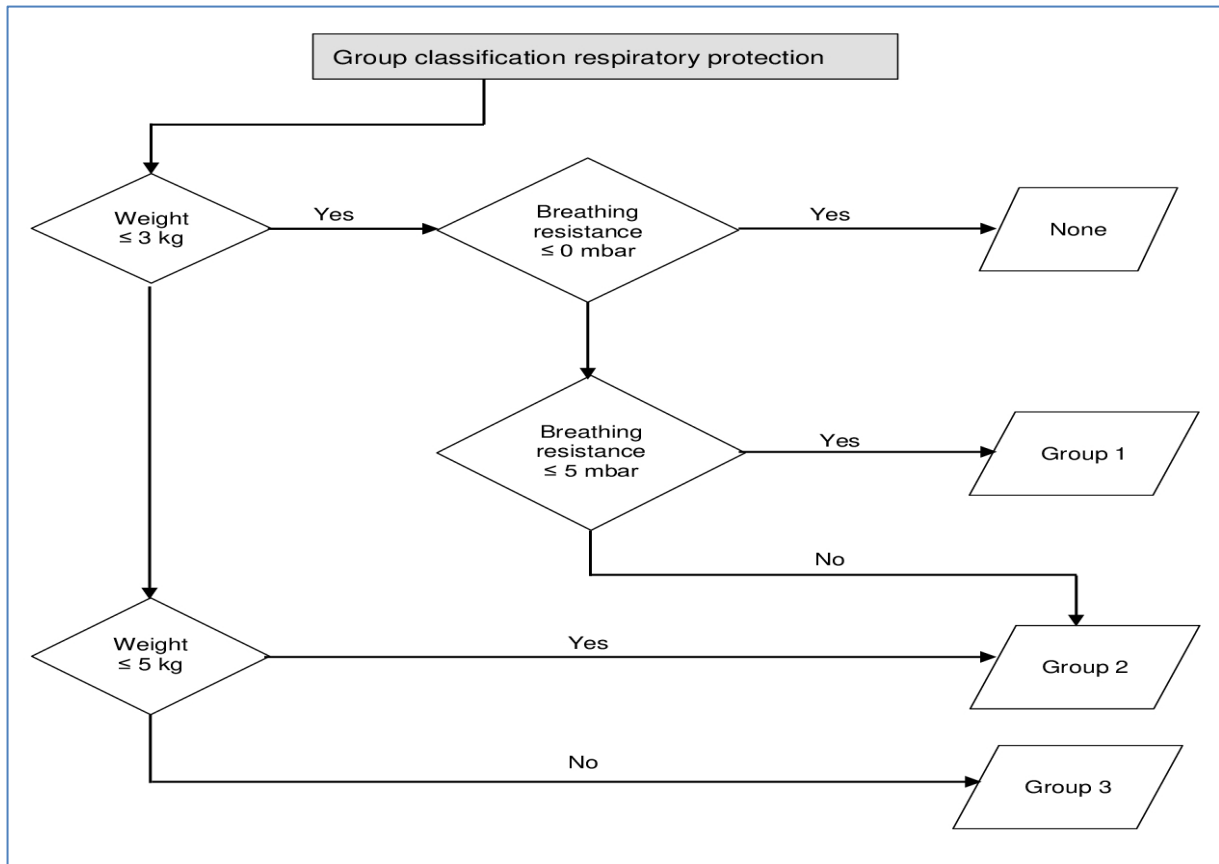
## **11.3 Medical examinations Germany (DGUV)**

In Germany, RPEs are classified into three groups and laid down in the Arbeitsmedizinische Regel (AMR) No. 14.2 "Einteilung von Atemschutzgeräten in Gruppen" [92]. See the overview in figure 12.1.

The German rule DGUV 112-190 [38] specifies for each group the occupational health examination to be carried out. Mandatory precautions are required when wearing RPE that are classified in grades 2 and 3. For RPE in group 1, the employer must provide preventive care. For RPEs that are not classified as a group, the employer must, at the employee's request, allow care to be provided according to the employee's wishes.

The precautionary measures must consider the working conditions, such as workload, climate and the service life of the RPE to be used. A risk analysis forms the basis of appropriate occupational health

care.



**Figure 12.1:** German grouping of RPE

According to the Arbeitsmedizinische Regel (AMR) No. 2.1 "Fristen für die Veranlassung/ das Angebot arbeitsmedizinischer Vorsorge" [93], the first examination must be started or offered within three months before the start of the activity. The table below shows the frequency of occupational health examinations.

**Table 12.1:** Repetition frequency occupational health examination RPE Germany [93]

| Age                       | 1st repetition | Subsequent repetitions |
|---------------------------|----------------|------------------------|
| Up to 50 years            | 12 months      | 36 months              |
| Older than 50 years:      |                |                        |
| Weight RPE up to 5 kg     | 12 months      | 24 months              |
| Weight RPE more than 5 kg | 12 months      | 12 months              |

## 12 Literature

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## ANNEXES

## ANNEX A: RPE Selection Form

Selection form for respiratory protective equipment according to ISO 16795-1:2016, adapted for RPE, standardized under EN standards.

|                                    |  |
|------------------------------------|--|
| Step 1: Data organization          | Step 6: Filter indication                          |
| Step 2: Description of the task    | Step 7: Calculation of the amount of breathing air |
| Step 3: Description of the hazards | Step 8: Task-related factors                       |
| Step 4: Determining the SPF        | Step 9: User-related factors                       |
| Step 5: Workload Review            | Step 10: Final selection                           |

| Step 1         | Organisation data |
|----------------|-------------------|
| Organization:  | Location:         |
| Filler's Name: |                   |
| Job Title:     |                   |
| Date:          |                   |

| Step 2   | Description of the task  |
|--|--|
| Describe the task and the work environment:  |  |
| Which officers perform the task?   |  |
| <p><b>Please note:</b> This form does not apply to Firefighting, Warfare Agents (Chemical, Biological, Radiological and Nuclear Substances -CBRN), Shipping or Escape Purposes - in these cases, seek advice from RPE supplier/manufacturer.</p> |  |
| (a) How long does the task take?<br>____h ____min<br><br>How many times per shift? _____per shift  | (b) What are the environmental conditions?<br><br>Temperature: ____°C<br>Humidity: ____%RH |

| Step 3  | Describe the dangers |   |
|---|----------------------|---|
| Is there a lack of oxygen or can there be a lack of oxygen?                 | Yes                  | Follow the regulations of Working Conditions Decree art. 3.5g.<br>If oxygen deficiency can occur, choose independent respiratory protection with an APF of 2000.<br><b>Continue to step 5</b>                               |
|   | No                   | <b>Continue to the next question</b>  |
| Is it known what contamination is present when performing the task?         | Yes                  | <b>Continue to the next question</b>  |
|   | No                   | I. Conduct research to determine the type of contamination.<br>II. If the type of contamination cannot be determined, opt for self-contained respiratory protection with an APF of 200.<br><b>Continue to step 5</b>        |
| Is the concentration of the contaminant known (by measuring or estimating)? | Yes                  | Continue - please complete the table below.   |
|   | No                   | I. If available, refer to the Industry Guidelines/Occupational Health & Safety Catalogue to determine the specific type of RPE and/or required APF —Continue to Step 5, or<br>II. Conduct exposure studies to determine the |

| Step 3   |  | Describe the dangers  |  |  |
|--|--|---|--|--|
|  |  | concentration.<br><b>Continue — Fill in the table below, or</b><br>III. If the concentration cannot be determined, opt for independent respiratory protection with an APF of 2000.<br><b>Continue to step 5</b> |  |  |
| Fill in the boxes below for particulate pollutants (dust, fibre, smoke, mist, fog)   |  |   |  |  |
| Substance<br>Name or CAS<br>number<br>(if applicable)  | (A)<br>Concentration <sup>6</sup><br>Measured or<br>Modelled<br>concentration in<br>air [ppm or<br>mg/m <sup>3</sup> ] | (B) IDLH<br>level <sup>7</sup> (if<br>applicable)<br>Immediate<br>danger to life or<br>health [ppm or<br>mg/m <sup>3</sup> ]  | (C) OEL<br>Occupational<br>exposure limit<br>value [in the<br>same unit as<br>(A)] | (D) Calculate<br>the minimum<br>required<br>protection<br>factor:<br><i>MRPF = A/C</i> |
| (I)  |  |   |  |  |
| (II)   |  |   |  |  |
| (III)  |  |   |  |  |
| (IV)   |  |   |  |  |
| Fill in the boxes below for gas/vapor contaminants   |  |   |  |  |
| Substance<br>Name or CAS<br>number<br>(if applicable)  | (A)<br>Concentration <sup>6</sup><br>Measured or<br>Modelled<br>concentration in<br>air [ppm or<br>mg/m <sup>3</sup> ] | (B) IDLH<br>level <sup>7</sup> (if<br>applicable)<br>Immediate<br>danger to life or<br>health [ppm or<br>mg/m <sup>3</sup> ]  | (C) OEL<br>Occupational<br>exposure limit<br>value [in the<br>same unit as<br>(A)] | (D) Calculate<br>the minimum<br>required<br>protection<br>factor:<br><i>MRPF = A/C</i> |
| (I)  |  |   |  |  |
| (II)   |  |   |  |  |
| (III)  |  |   |  |  |
| (IV)   |  |   |  |  |
| Result of step 3   |  |   |  |  |
| <b>Which of the contaminant(s) from the above tables has the highest risk ratio (MRPF) in (D)? Make a note of it on the right.</b><br><br>If the risk ratio is <1, RPE is not required UNLESS national regulations or an industry guideline applies to the contamination |  |   |  | (E) Highest<br>Risk Ratio<br>(MRPF)  |

| Result of step 3 - follow-up  |     |  |
|---|-----|--|
| <b>For contaminants with a LEL (Lower Explosion Limit): is the concentration in (A) higher than 10% of the LEL value?</b> | Yes | Stop work. Seek advice from the SIR and/or RPE supplier/manufacturer.  |
|   | No  | <b>Continue to the next question</b>   |
| <b>For contaminants with an IDLH value: is the concentration in (A) higher than the IDLH value (B)?</b>                   | Yes | Select independent breathing air (If a compressed air line system is used, it must be equipped with emergency air supply with automatic changeover device for escape conditions) |
|   | No  | <b>Continue to step 4</b>  |

<sup>6</sup> Use a conservative approach, e.g. the maximum expected concentration, or the 70% confidence limit of the 95 percentiles of exposure when sufficient measurement data are available.

<sup>7</sup> <https://www.cdc.gov/niosh/idlh/default.html>

| Step 4  | Determining the Protection Factor |    |    |    |            |
|---|-----------------------------------|----|----|----|------------|
| Circle the number greater than the risk ratio (MRPF) as given in (E).<br>(classification based on the UK APFs from NEN-EN-529:2005 <sup>8</sup> ) | 4                                 | 10 | 20 | 40 | 2000       |
| <b>Minimum APF Required</b>   |                                   |    |    |    | <b>APF</b> |

| Step 5  | Workload Assessment   |  |
|---|---|--|
| <p>There are four classes of workload. Choose the workload that best matches the task at hand.</p> <p>From workload W2 onwards, inappropriate types of RPE are listed (as a rule of thumb, not recorded as part of EN standardisation).</p> |   |  |
| Class   | Definition  | Rule of thumb:<br>incompatible types of RPE  |
| W1  | Light workload: Seated work, such as assembling or sorting light materials or standing work that does not involve the use of heavy tools. |  |
| W2  | Medium workload: continuous hand and arm work, such as shovelling, high-pressure spraying, blasting and the use of concrete hammers.      | FFP (EN-149)<br>Half and full-face masks with filter (EN-136, EN-140, EN-405, EN-1827) |
| W3  | Heavy workload: heavy manual work such as digging, climbing on elevations or ladders and crawling.  | See above for W2<br>PAPR (EN-12941 and EN-12942)                                       |
| W4  | Maximum workload: uninterrupted work of less than 5 minutes without breaks Rescue and firefighting work at maximum intensity.             | See above for W3   |
| <b>Minimum Workload Class Required</b>  |   | <b>W</b>   |

| Step 6   | Filter Identification |  |
|--|-----------------------|--|
| <p>Use the information from the previous steps to determine an appropriate filter type and filter class:<br/>suitable for the hazard, concentration and duration of operation applicable to the task.<br/>If necessary, seek advice from RPE supplier/manufacturer.</p> <p>If you want to start using independent breathing air, go to step 7.</p> |                       |  |
| Has a suitable filter been identified?   | Yes                   | <p><b>Filter type and filter class:</b></p> <p><b>Filter breakdown time (in minutes) under the conditions of use</b> (determined with e.g. a 'service lifetime calculator'):</p> <p><b>Recommendation received from:</b></p> <p><b>Proceed to step 8</b></p> |
|  | No                    | Select Independent Breathing Apparatus<br><b>Continue to step 7</b>  |

| Step 7 | Calculation of the amount of breathing air |
|--------|--|
|--------|--|

<sup>8</sup> For a specific brand/type of RPE, it is possible to deviate from these standard APF values on the basis of a SWPF study.

|   |  |
|---|--|
| <b>Calculate the volume of breathing air required for the duration of the task, including entry and exit, by using the information in step 2 and step 5, using the calculations below. If the workload changes, the usable duration of breathing air changes.</b>                                   |  |
| <b>Calculation based on task duration and mean respiratory minute volume</b>  | <b>Minimum amount of breathing air</b> |
| Job Duration (min) x 30 L/min for W1  | _____ Litres of breathing air required |
| Job Duration (min) x 40 L/min for W2  |  |
| Job Duration (min) x 50 L/min for W3  |  |
| Job Duration (min) x 65 L/min for W4  |  |
| When using a self-contained breathing apparatus (SCBA EN137), the required capacity must be rounded off. The minimum capacity required in litres is the calculated capacity, rounded up in 150 L increments if less than 900 L is required, and in 300 L increments if more than 900 L is required. |  |
| If the required capacity of a self-contained breathing apparatus (SCBA EN137) for the service life is greater >2430 L (9 litre cylinder 300 bar <sup>9</sup> ), then a compressed air line system should be chosen.   |  |
| <b>Minimum required capacity (rounded)</b>  | <b>Liters</b>                          |

| <b>Step 8</b>  | <b>Task-related factors</b> |   |
|--|-----------------------------|---|
| Is the task performed in a confined space (e.g., barrel, well, chamber, tank, trench, pipe, sewer, flue, or well)? | Yes                         | Consult industry-specific occupational health and safety catalogues and Basic Inspection module SIPFE hazards of the Dutch Labour Inspectorate. If necessary, seek additional advice. |
|  | No                          | <b>Continue</b>   |
| Is the RPE used continuously for more than 1 hour?   | Yes                         | Consider motor-driven or independent RPE.   |
|  | No                          | <b>Continue</b>   |
| Is the contamination irritating to the eyes?   | Yes                         | Use a full-face mask, helmet, or hood that covers the face. There are also 'loose fitting' systems that protect the neck and/or shoulders.  |
|  | No                          | <b>Continue</b>   |
| Does the task require mobility, such that the use of air ejector hoses is impractical?                             | Yes                         | Do not select a type of RPE with an air ejector hose.   |
|  | No                          | <b>Continue</b>   |
| Is accurate communication necessary to provide safety-critical instructions when RPEs are worn?                    | Yes                         | Select RPEs equipped with a speech diaphragm or additional means of communication.  |
|  | No                          | <b>Continue</b>   |
| Does the task create sparks, molten metal, or UV radiation?  | Yes                         | Choose a suitable type or seek RPE manufacturer/supplier advice.  |
|  | No                          | <b>Continue</b>   |
| Is the atmosphere in the work area potentially explosive or flammable?   | Yes                         | Choose an RPE that is intrinsically safe (ATEX)   |
|  | No                          | <b>Continue</b>   |
| Is the atmosphere in the workplace corrosive?  | Yes                         | Get advice from RPE Manufacturer/Supplier   |
|  | No                          | <b>Continue</b>   |

| <b>Step 9</b>   | <b>User-related factors</b> |
|---|-----------------------------|
| <i>Answer the following questions for each wearer</i> |                             |

<sup>9</sup> The amount of breathing air available is calculated by multiplying the cylinder's water volume by the pressure. In compressed air cylinders with a pressure >200 bar, the compression efficiency decreases and the correction factor of 0.9 is applied (van der Waal's equation).

|   |     |   |
|---|-----|---|
| Does the user have in the sealing area of the RPE on the face: Stubble, beard, moustache, sideburns, deep facial marking, or facial jewellery <sup>10</sup> ? | Yes | Select 'loose fitting' RPE.   |
|   | No  | <b>Continue</b>   |
| Are glasses with corrective lenses worn?  | Yes | Select an RPE that can be used with glasses with corrective lenses. <sup>11</sup>   |
|   | No  | <b>Continue</b>   |
| Are other types of personal protective equipment (PPE) worn at the same time (head, eye or hearing protection, protective clothing, etc.)?                    | Yes | Make sure that the selected RPE and other PPE required for the job do not interfere with each other. Consider RPE with integrated head, face, eye, or hearing protection. |
|   | No  | <b>Continue</b>   |
| Does the use of this RPE in conjunction with the tasks performed require an assessment of the medical fitness of the RPE user?                                | Yes | Seek professional advice from the occupational health and safety service provider.  |
|   | No  | <b>Continue</b>   |

|  |                 |   |                                      |
|--|-----------------|---|--------------------------------------|
| <b>Step 10</b>   |                 | <b>Final selection</b>                                    |                                      |
| <b>Minimum filter class RPE</b>  |                 |   |                                      |
| Fill in the boxes below with the information collected.  |                 |   |                                      |
| <b>Required Protection Level (APF)</b>   | <b>Workload</b> | <b>Required filter and class Breakdown time (minutes)</b> | <b>Suitable type RPE with filter</b> |
| (see step 4)   | (see step 5)    | (see step 6)  |                                      |
| <b>APF</b>   | <b>W</b>        |   |                                      |
| <b>Minimum class of self-contained breathing air RPE</b>   |                 |   |                                      |
| Fill in the boxes below with the information collected.  |                 |   |                                      |
| <b>Required Protection Level (APF)</b>   | <b>Workload</b> | <b>Minimum required capacity of breathing air</b>         | <b>Suitable Type Independent RPE</b> |
| (see step 4)   | (see step 5)    | (see step 7)  |                                      |
| <b>APF</b>   | <b>W</b>        |   |                                      |
| Choose an RPE that meets the above requirements. If such an option is not currently available on the market, select the next higher class. If the selected RPE has a tight-fitting seal, perform a face-fit test on the user using that type of RPE. |                 |   |                                      |
| <b>Selected RPE:</b>   |                 |   |                                      |

<sup>10</sup> See also NEN-EN529:2005 D4.2 Facial characteristics.

<sup>11</sup> See also NEN-EN529:2005 D4.3 Spectacles and D4.4 Contact lenses.

# ANNEX B: Laws and Regulations and Overview of Respiratory Protection Standards

## Regulations and standards

### A1 Dutch General Working Conditions Legislation (in short)

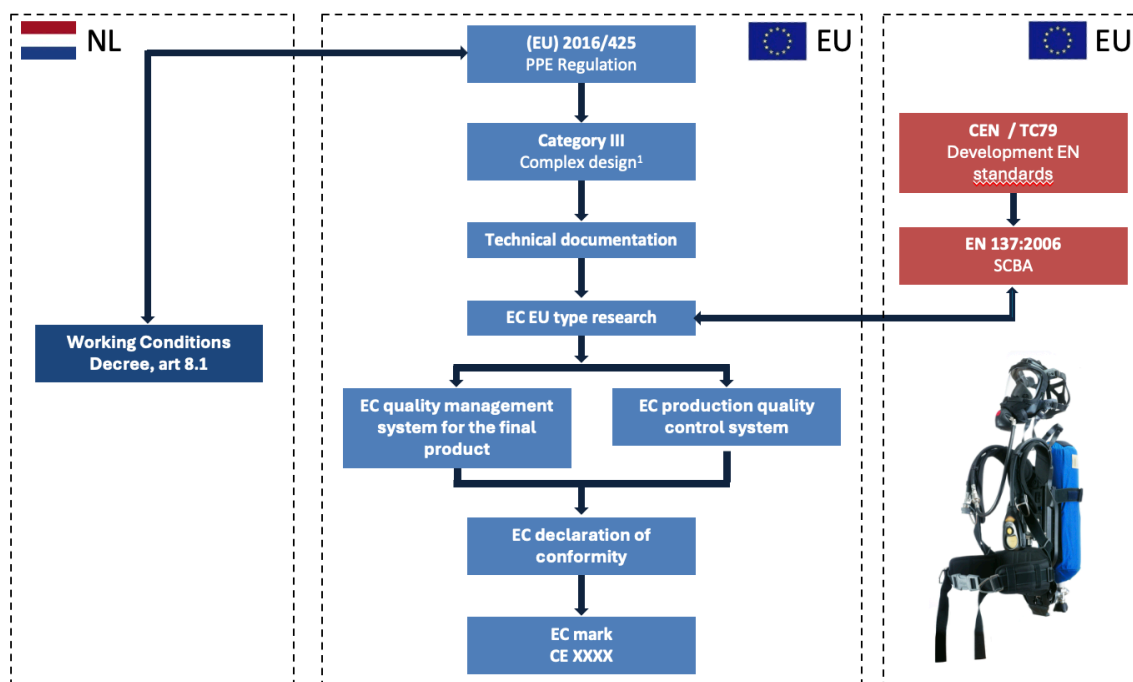
Everyone must be able to do his or her work in safe and healthy conditions. For this purpose, there is the Working Conditions Act; it forms the basis of the overall Working Conditions legislation. In short, the Working Conditions Act is structured as follows:

- Working Conditions Act:  
The Working Conditions Act is the basis of all legislation in the field of working conditions. This Act contains general provisions that apply to all places where work is performed. The concrete implementation of these guidelines can be found in the Working Conditions Decree and the Working Conditions Regulations.
- Working Conditions Decree:  
The Working Conditions Decree describes the mandatory rules that both the employer and the employee must adhere to; the rules are intended to prevent occupational risks. Different and/or additional rules may be included for a number of sectors and certain categories of employees.
- Working Conditions Regulations:  
The third level is the Working Conditions Scheme and a further elaboration of the Working Conditions Decree. These are detailed (mandatory) regulations. For example, the requirements of a qualified employee, what work equipment must meet and how an occupational health and safety service must perform its statutory tasks exactly.

### A2 Performance requirements for respiratory protective equipment

#### A2.1 PPE Regulation EU 2016/425

After a transition period, the Regulation (EU) 2016/425 (Personal Protective Equipment; PPE) is fully in force on 21 April 2018. This PPE Regulation is a binding law that sets clear and detailed requirements for PPE in all EU member states. Previously, this was Directive 89/686/EEC. Only PPE that meets the requirements in Regulation (EU) 2016/425 is suitable and permitted for use. PPE must bear a CE marking. With this CE marking, the manufacturer or importer of the PPE demonstrates that it meets the minimum requirements.



<sup>1</sup> Classification and classification of PPE according to the Regulation. Category III (complex design) includes, among other things, self-contained breathing apparatus (SCBA) EN 137:2006.

**Figure B.1:** Legislative and regulatory framework Respiratory Protective Equipment

Within the regulation, PPE is classified into risk categories against which it must be protected.

Respiratory protection falls into the highest risk category, category III. In the case of the highest risk category, additional requirements are imposed on the quality assessment of the PPE.

For PPE in category I, an internal production control by the manufacturer itself is sufficient. In the case of PPE in categories II and III, the CE marking must be type-approved. To do this, the manufacturer must always use a notified body.

Those who place PPE on the European market indicate in which composition the PPE may be used with other PPE and/or accessories. During the type of approval, the notified body checks, among other things, whether the composition is compatible with the protective requirements of the PPE to be inspected. A list of conformity is drawn up and forms part of the inspection certificate. Making other parts and/or changes to the PPE other than those mentioned in the inspection certificate makes the repairer and/or assembler a manufacturer of a "new" product. If the inspection certificate is deviated from, the assembler must go through all the steps for a new (CE) type approval with the "new" product in accordance with the PPE regulation.

A category II and III product also mention a 4-digit code with the CE mark that refers to the notified body that monitors the quality, carries out random checks and tests. The type-examination certificate issued by a notified body has a maximum validity period of 5 years with the entry into force of the new regulation. All old type-examination certificates without a validity period will expire as of April 2023.

## **A2.2 Commodities Act Decree on Personal Protective Equipment**

With the advent of the new European PPE Regulation, the Dutch Commodities Act Decree PPE has been amended, and the national interpretation and application has lapsed. All that remains is a reference to the European PPE regulation. The new name is: Commodities Act Decree Personal Protective Equipment 2018.

## **A2.3 Working Conditions Decree**

Chapter 8 of the Working Conditions Decree sets requirements for PPE. Article 8.1 describes the general requirements for PPE. Among other things, it stipulates that PPE:

- must comply with the Commodities Act Decree on Personal Protective Equipment.
- must be suitable for the hazards to be avoided without themselves constituting an increased hazard.
- must correspond to existing conditions at the workplace.
- must be adapted to ergonomic requirements.
- are suitable for the wearer after the necessary adjustments.
- must be used in accordance with the instructions for use.

Article 8.2 sets out requirements for the choice of PPE. Among other things, it stipulates that:

- an RA&E must be carried out describing why PPE is necessary and why the hazards cannot be avoided by other means.
- there should be a description of the characteristics of the PPE in order to be able to overcome the hazards identified. In doing so, account must be taken of any sources of danger that the PPE itself may pose.
- an RA&E must be carried out on the PPE in question in order to identify whether the hazards against which it is intended to protect and/or which the PPE itself constitutes have been overcome.

## **A2.4 EU standards**

The PPE Regulation sets minimum requirements for PPE that can be used in the EU. Within the EU, harmonised standards have been drawn up for almost all types of respiratory protective equipment. Standards are agreements that market parties make in consensus with each other about the minimum quality and safety of PPE. Harmonised standards, which set out the minimum requirements that an RPE must meet, can demonstrate that products or services meet the technical requirements of the relevant EU legislation.

Harmonised European standards are drawn up by CEN/Cenelec. For respiratory protective devices, this is done by CEN's Technical Committee CEN/TC 79 "Respiratory protective devices". In the Netherlands, these are taken over and published by NEN. Examples include:

- NEN-EN 136 Full face masks
- NEN-EN 137 Self-contained breathing apparatus with a full-face mask

- NEN-EN 149 Filtering half masks to protect against particles
- NEN-EN 12021 Breathing gas for respirators
- NEN-EN 14387 Gas filter(s) and combination filter(s)

Within a few years, the European harmonised standards for respiratory protection will be replaced by the globally harmonised ISO standards. Within the ISO standards, respiratory protection is viewed in a fundamentally different way. The focus is on the user and how they should be protected in their working conditions. At the same time, the new ISO standards opt for a system approach and not a component approach as in the current EN standards. The worldwide standards for respiratory protective equipment are developed by the ISO/TC 94/SC15 committee. The published standards are reviewed every 5 years to see whether they are still sufficiently up-to-date and normative.

### **A2.5 The Vienna Agreement**

The Vienna Convention lays the foundations for far-reaching cooperation between the CEN (European Committee for Standardization) and ISO (International Organization for Standardization) in the development of European and global standards. As a result of this convention, newly developed standards are assessed by CEN/ISO members. During this consultation round, the EU member states (CEN members) are asked in particular to examine the draft standards in the light of European directives and specific European situations and, if necessary, to submit European derogations on this basis, which will be voted on in a follow-up phase on the approval of the 'Vienna agreement' on the relevant ISO standard. An accepted European standard must therefore be adopted and applied as a national standard by all CEN members, including those who voted against.

There is a tendency for the current EN and ISO standards describing the performance requirements for respiratory protection to become increasingly similar. At the moment, there is talk of a global standard for RPE, among other things. This is only possible if the new ISO standards are adopted by the EU member states under the Vienna agreement. This is not the case at the moment. Once the ISO standards have been adopted, a transition period from EN standards to ISO standards for RPE will come into effect.

See also:

<https://www.cencenelec.eu/about-cen/cen-and-iso-cooperation/>

<https://www.iso.org/committee/291088.html>

[https://www.nen.nl/media/PDF/Handleiding\\_Commissieleden\\_2015-01\\_02\\_nieuw\\_logo.pdf](https://www.nen.nl/media/PDF/Handleiding_Commissieleden_2015-01_02_nieuw_logo.pdf)

## **A3 Requirements for use of respiratory protective equipment**

### **A3.1 EU Directive 89/656/EEC**

Council Directive 89/656/EEC of 30 November 1989 lays down the minimum safety and health requirements for the use of personal protective equipment by workers at the workplace. The provisions referred to in the Directive are largely contained in Occupational Health and Safety Decrees.

### **A3.2 Dutch Working Conditions Legislation in the event of exposure to hazardous substances**

Workplaces must be designed in such a way that there is no risk of suffocation, intoxication, poisoning, fire or explosion (SIPFE hazards). If these dangers do exist, effective measures must be taken.

According to the Working Conditions Decree (Article 3.5g), there is in any case the following:

- risk of asphyxiation if the atmosphere contains less than 18% oxygen by volume.
- risk of intoxication or poisoning if the concentration of the substances in question in the atmosphere exceeds the limit values,
- risk of fire or explosion if the concentration of oxygen in the atmosphere exceeds 21 percent by volume or the concentration of flammable gases or vapours exceeds 10 percent of the lower operating limit.

Respiratory protective equipment is used in case of possible inhalation exposure to hazardous substances. In order to determine the appropriate level of protection for the selection of a respiratory protective device, the nature, degree and duration of the exposure must be inventoried in accordance with Article 4.2 of the Working Conditions Decree (so-called RA&E). On the basis of the RA&E (Article 8.2 of the Working Conditions Decree), it must be determined which type of respiratory protection is suitable. In some situations, it is important to look not only at the inhalation exposure but also at the possible contribution due to skin absorption or insufficient hygiene. For some substances it is possible to demonstrate the effectiveness of (breath) protective equipment and hygiene measures through

biological monitoring.

Article 8.3 of the Working Conditions Decree sets requirements for the availability and use of PPE. Among other things, it stipulates that:

- PPE should be made available in sufficient numbers.
- Obligation to use PPE.
- PPE needs to be maintained, repaired and kept clean.
- Necessary replacements must be made for proper functioning.

Chapter 4 of the Working Conditions Decree sets additional requirements for the use of PPE in some cases.

In the case of Carcinogens and Mutagens:

- PPE must be stored in a designated place in accordance with instructions and cleaned and checked after each use (Article 4.20, paragraph 5 of the Working Conditions Decree).
- For work with asbestos, the following also applies art. 4.45 Working Conditions Decree (no shower room mandatory in case of risk class 1. For risk classes 2 and 2A, however, the obligation for a decontamination unit applies. For activities in risk class 2 and 2A, there is an annual obligation to perform a face fit test according to the HSE282/28 protocol (UK) by a recognized face fit tester. In the meantime, this protocol has been transferred to the HSE INDG 479 protocol. A face fit test should be performed on any type of respiratory protective equipment in use. The company and the person who carries out face fit tests must be certified and recognised (Article 4.27 of the Working Conditions Regulations and Articles 14 and 34 of the Certification Scheme for the Process Certificates for Asbestos Inventory and Asbestos Removal).

In the case of biological agents (Article 4.89 of the Working Conditions Decree):

- PPE should be stored in a designated place and cleaned and checked after each use.
- PPE must be removed (safely) when leaving the workplace and stored in a different place from other clothing
- PPE is disinfected, cleaned or, if necessary, destroyed.
- PPE may only be introduced into the company for the purpose of cleaning, disseminating or destroying it. In that case, the transport must take place in a suitable closed package.

According to Article 8 of the Working Conditions Act, information and instruction must be provided in the use of PPE. Among other things, it states that:

- Employees must be aware of their purpose and operation and the way in which they should use it.
- The employer must ensure the correct use of personal protective equipment.

According to Article 11 of the Working Conditions Act, employees are obliged to use PPE. Among other things, it stipulates that:

- PPE must be used correctly and stored in a designated location.
- Employees are obliged to participate in information and training.
- The safety or health hazards noticed must be reported immediately to the employer or supervisor.

See also:

Article 3.5g of the Working Conditions Decree

Article 4.27 of the Working Conditions Regulations

<https://zoek.officielebekendmakingen.nl/stcrt-2018-68771.html>

<https://safetysign.nl/erkenningsregelingen/erkend-face-fittestester/>

<https://www.instituutcec.nl/face-fittestester/>

Chapter 8 Working Conditions Decree

### **A3.3 EN 529**

EN 529 is a standard with regard to RPE and provides recommendations for the selection, use, care and maintenance of this RPE. EN 529 is a practice guideline. EN 529 is not about the RPE itself but deals with the organisation around it: how are hazards recognised, identified and evaluated (RA&E) and how are the right resources selected, users trained, and maintenance carried out. Particular attention is paid to a structural organisation of the entire process.

In the appendices to the standard, Annex C shows the determined nominal protection factors (NPF)

and assigned protection factors (APF) per type of respiratory protective equipment per country. Annex D provides guidelines on medical fitness, use of contact lenses, spectacles and facial hair. In the case of tight-fitting respirator, a maximum shaving period of 8 hours before the start of the work shift (D4.2) is maintained. If the facial hair cannot be shaved off due to medical and/or religious reasons, it can be considered to use respiratory protection with a "hood" or hood (loose fitting respirator). The use of lenses is discouraged in rooms or atmospheres with a concentration above the Immediately Dangerous To Life or Health (IDLH) limit (D4.4). In these areas, goggles are recommended which fit fully integrated into the mask (D4.3).

#### **A3.4 NVBR guideline for the maintenance plan for respiratory protective equipment**

In 2002, the Dutch Association for Fire Service and Disaster Management (NVBR) drew up guidelines for organisations that manage respiratory protective equipment in respiratory protection workshops, the so-called Maintenance Plan for Respiratory Protective Equipment. According to this guideline, maintenance of respiratory protective equipment is classified into 4 levels:

- Level 1: user test before use
- Level 2: After-use maintenance
- Level 3: periodic maintenance
- Level 4: annual maintenance

The actual maintenance of respiratory protective equipment is divided into three categories in this Directive:

- Routine maintenance: all activities aimed at organizing and carrying out management and maintenance on the basis of the obligations arising from, among other things, knowledge, regulations, warranty provisions and safety considerations.
- Corrective maintenance: technical maintenance that focuses on repairing and repairing malfunctions and defects that have occurred.
- Preventive maintenance: the type of maintenance that focuses on preventing malfunctions during certain periods of use or the duration of operational functioning.

This sector guideline is the minimum requirement that maintenance must meet within fire brigade organizations.

#### **A3.5 Industrial Cleaning Foundation (SIR)**

The aim of the Foundation for Industrial Cleaning (SIR) is to promote and regulate safe working practices in the industrial cleaning industry. During industrial cleaning, employees may be exposed to hazardous substances, gases or vapours. The employees who carry out this work must have knowledge of the working methods and be trained to work with the resources. For this reason, the SIR draws up regulations for people, resources and working methods.

The regulations are laid down as guidelines in the SIR Respiratory Protection Handbook. The purpose of such guidelines is to achieve standardization in the preparation, execution and termination of work with respiratory protection in such a way that the safety of those directly and indirectly involved is guaranteed. In addition, the handbook is a guideline for the employer and the self-employed to support the formation of a respiratory protection program by providing the conditions, knowledge and resources required for an effective implementation in a structured manner.

All SIR participants (SIR member companies) have committed themselves to comply with these guidelines. See also: [www.sir-safe.nl](http://www.sir-safe.nl)

## **A4 Other international regulations and guidelines**

### **A4.1 Germany**

The use of respirators in Germany is regulated by DGUV Rule 112-190 "Benutzung von Atemschutzgeräten". It is mandatory to follow this directive unless a comparable level of safety can be achieved by other means.

The Directive applies to the selection and use of RPE in normal operations, rescue work and escape situations. The Directive regulates the classification, marking, selection, use and maintenance of types of RPE. It contains specific requirements that respiratory protection users and maintenance personnel must meet in terms of their education, training and instruction. This regulation does not apply to fire brigades and companies covered by the Mining Act insofar as they have their own regulations.

The DGUV has also published a publication (DGUV 212-190) describing how respiratory protection covered by the new ISO guidelines can be classified and selected. Specifically, the ISO series 16973 "Respiratory protective devices - classification" and 16975 "Respiratory protective devices - selection, use and maintenance" are implemented. The information therefore complements DGUV Regulation 112-190 "Use of RPE", which describes the selection and use of RPE according to DIN and EN classification and contains information on the use of RPE.

#### **A4.2 United Kingdom**

The use of respiratory protective equipment in the workplace is regulated in the United Kingdom (UK) by the HSG53 Directive. This guideline is issued by the Health and Safety Executive. Following this guideline is not mandatory, unless specifically stated. By applying this guideline, the laws and regulations in the UK are complied with. The guideline indicates when respiratory protection can be used using a simple step-by-step approach. It helps to determine what level of protection is appropriate for a particular hazardous substance and how to choose respiratory protection that is appropriate for the wearer, the task and the working environment. It also contains advice on how to keep the chosen respiratory protection functional

Performing face fit tests is regulated in HSE INDG479 (previously this was HSE OC 282/28). This guideline gives:

- information on face fit testing methods.
- information on what can be achieved with a face fit test.
- and the most important information to be included in a face fit test report.

Further advice on the practicalities of suitability testing is provided by the British Safety Industry Federation (BSIF) through the Fit2Fit organisation. Face fit tests must be performed by an expert person. Proficiency can be demonstrated by accreditation under the Fit2Fit RPE Fit Test Provisions Accreditation Scheme. This scheme has been developed by the BSIF, together with industry stakeholders, and is supported by the HSE. The scheme is not mandatory, and employers are free to take other measures to comply with the law.

See also: <https://www.fit2fit.org>

#### **A4.3 United States**

Respiratory protection requirements are regulated by law in the United States in the OSHA 1910.134 legislation. Among other things, the selection, performance requirements, use, maintenance and face fit tests have been recorded. Respiratory protective equipment used in working conditions must be NIOSH approved. For firefighting applications, these NFPA must be 'approved'.

The technical and functional requirements for NIOSH or NFPA 'approved' respiratory protection are different from requirements for RPE in Europe (EN standards). As a result, respiratory protective equipment used in the USA is not easily comparable to the respiratory protective equipment used in Europe. As a result, it is also not possible to compare assigned protection factors (APFs) from the OSHA legislation with APFs used in Europe.

In many international companies in the Netherlands, face-fit tests are carried out in accordance with OSHA regulations. The requirements for face fit testing are described in OSHA 1910.134 App A.

### **A5 Overview Laws and regulations**

Netherlands:

- Working Conditions Decree. Staatsblad 1997, no. 60, 25-02-1997
- Commodities Act Decree on Personal Protective Equipment 2018. Official Gazette 2018, No. 104, 17-04-2018.

Europe:

- Directive 89/656/EEC of 30 November 1989 on the minimum safety and health requirements for the use of personal protective equipment by workers at the workplace. Official Journal of the European Union, No L393/18, 30-12-1989.
- Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016 on personal protective equipment and repealing Council Directive 89/686/EEC. Official Journal of the

European Union, No L81/51, 31-03-2016.

CEN:

- Community face coverings - Guide to minimum requirements, methods of testing and use. CWA 17553. June 2020. CEN Workshop Agreement.

Germany:

- Benutzung von Atemschutzgeräten. DGUV Rule 112-190; December 2011. Deutsche Gesetzliche Unfall-versicherung e.V. (DGUV).
- Klassifizierung und Auswahl von Atemschutzgeräten nach ISO-Standards. DGUV Information 212-190; November 2020.

United Kingdom:

- Guide to Implementing an Effective Respiratory Protective Device Programme. BS 4275; 1997 Edition, December 15, 1997. (withdrawn in 2005)
- Respiratory protective devices. Recommendations for selection, use, care and maintenance. Guidance document. BS EN 529:2005, November 2005.
- Guidance on respiratory protective equipment (RPE) fit testing. INDG479 (rev1), published 03/19. Health and Safety Executive.
- Personal protective equipment at work. Personal Protective Equipment at Work Regulations 1992. Guidance on Regulations. L25 (Third edition) Published 2015. Health and Safety Executive.
- Respiratory protective equipment at work. A practical guide. HSG53 (Fourth edition, published 2013). Health and Safety Executive.

United States:

- <http://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.134>
- <https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.134AppA>

## B Overview of Standards

Sorted by standard number (names in Dutch).

| <b>B1 Respiratory protective devices</b> |  |
|--|--|
| NEN-EN 133: 2001                         | Ademhalingsbeschermingsmiddelen - Classificatie  |
| NEN-EN 134: 1998                         | Ademhalingsbeschermingsmiddelen – Benaming van onderdelen  |
| NEN-EN 135: 1999                         | Ademhalingsbeschermingsmiddelen – Lijst van gelijkwaardige termen  |
| NEN-EN 136: 1998 + C2:2007               | Ademhalingsbeschermingsmiddelen – Volgelaatsmaskers – Eisen, beproevingsmethoden, merken   |
| NEN-EN 137: 2006                         | Ademhalingsbeschermingsmiddelen – Onafhankelijk ademluchttoestel met een volgelaatsmasker – Eisen, beproeving en merken  |
| NEN-EN 138: 1995                         | Ademhalingsbeschermingsmiddelen – Zelfaanzuigende ademhalingsbeschermingsmiddelen voor gebruik met volgelaatsmaskers, halfmaskers of een mondstukgarnituur – Eisen, beproeving, merken |
| NEN-EN 140: 1998                         | Ademhalingsbeschermingsmiddelen – Halfmaskers en kwartmaskers – Eisen, beproeving, merken  |
| NEN-EN 142: 2002                         | Ademhalingsbeschermingsmiddelen – Mondstukgarnituren – Eisen, beproeving, merken   |
| NEN-EN 143: 2021                         | Ademhalingsbeschermingsmiddelen – Deeltjesfilters – Eisen, beproeving, merken  |
| NEN-EN 144-2: 2018                       | Ademhalingsbeschermingsmiddelen – Afsluiters voor gasflessen – Deel 2: Verbindingen voor uitlaataansluitingen  |
| NEN-EN 144-3: 2003                       | Ademhalingsbeschermingsmiddelen – Afsluiters voor gasflessen – Deel 3: Uitlaatverbindingen voor Nitrox en zuurstof duikgas   |
| NEN-EN 145: 1997                         | Ademhalingsbeschermingsmiddelen – Onafhankelijk kringloopademhalingstoestel met samengeperste zuurstof of samengeperste zuurstof-stikstof – Eisen, beproeving, merken                  |
| NEN-EN 148-1: 2019                       | Ademhalingsbeschermingsmiddelen – Schroefdraad voor gelaatstukken – Deel 1: Standaard Schroefverbinding  |
| NEN-EN 148-2: 1999                       | Ademhalingsbeschermingsmiddelen – Schroefdraad voor gelaatstukken – Deel 2: Centrale schroefkoppeling  |

| <b>B1 Respiratory protective devices</b> |  |
|--|--|
| NEN-EN 148-3: 1999                       | Ademhalingsbeschermingsmiddelen – Schroefdraad voor gelaatstukken – Deel 3: Schroefkoppeling M45x3   |
| NEN-EN 149: 2001 + A1: 2009              | Ademhalingsbeschermingsmiddelen – Filtrerende halfmaskers ter bescherming tegen deeltjes – Eisen, beproeving, merken   |
| NEN-EN 269: 1995                         | Ademhalingsbeschermingsmiddelen – Aangedreven slangademhalingstoestellen met een kap – Eisen, beproeving, merken   |
| NEN-EN 405: 2002 + A1: 2009              | Ademhalingsbeschermingsmiddelen – Filtrierend halfmasker ter bescherming tegen gassen of gassen en stof – Eisen, beproeving, merken  |
| NEN-EN 529: 2005                         | Ademhalingsbeschermingsmiddelen – Aanbevelingen voor keuze, gebruik, verzorging en onderhoud - Praktijkrichtlijn   |
| NEN-EN 1827: 1999 + A1: 2009             | Ademhalingsbeschermingsmiddelen – Halfmaskers zonder inademventiel en met deelbare filters ter bescherming tegen gas of gas en deeltjes of tegen alleen deeltjes – Eisen, beproeving, merken |
| NEN-EN 12021: 2014                       | Ademhalingsbeschermingsmiddelen – Ademgas voor ademhalingstoestellen   |
| NEN-EN 12083: 1998/C1:2000               | Ademhalingsbeschermingsmiddelen – Niet op de adempluchtaansluiting gemonteerde filters – Deeltjesfilters, gasfilters en gecombineerde filters -Eisen, beproeving, merken                     |
| NEN-EN 12941:1998/A2:2008 en             | Ademhalingsbeschermingsmiddelen – Aangedreven filters gecombineerd met een helm of een kap – Eisen, beproeving, merken   |
| NEN-EN 12942: 1998/A2:2008 en            | Ademhalingsbeschermingsmiddelen – Aangedreven filters gecombineerd met volgelaatsmaskers, halfgelaatsmaskers of kwartgelaatsmaskers – Eisen, beproeving, merken                              |
| NEN-EN 13274-1: 2001                     | Ademhalingsbeschermingsmiddelen – Beproevingmethoden – Deel 1: Bepaling van lekkage naar binnen en totale lekkage naar binnen  |
| NEN-EN 13274-2: 2019                     | Ademhalingsbeschermingsmiddelen – Beproevingmethoden – Deel 2: Praktische prestatieproeven   |
| NEN-EN 13274-3: 2001                     | Ademhalingsbeschermingsmiddelen – Beproevingmethoden – Deel 3: Bepaling van de ademhalingsweerstand  |
| NEN-EN 13274-4: 2020                     | Ademhalingsbeschermingsmiddelen – Beproevingmethoden – Deel 4: Vlambestendigheid   |
| NEN-EN 13274-5: 2001                     | Ademhalingsbeschermingsmiddelen – Beproevingmethoden – Deel 5: Klimaatomstandigheden   |
| NEN-EN 13274-6: 2002                     | Ademhalingsbeschermingsmiddelen – Beproevingmethoden – Deel 6: Bepaling van het kooldioxidegehalte van de inhalatielucht   |
| NEN-EN 13274-7: 2019                     | Ademhalingsbeschermingsmiddelen – Beproevingmethoden – Deel 7: Bepaling van het doordringingsvermogen van deeltjesfilters  |
| NEN-EN 13274-8: 2003                     | Ademhalingsbeschermingsmiddelen – Beproevingmethoden – Deel 8: Bepaling van verstopping door dolomietstof  |
| DIN 14092-7: 2012                        | Feuerwehrrhäuser - Teil 7: Werkstätten (NB: In april 2023 is een concept (norm-ontwerp) van deze norm verschenen)  |
| NEN-EN 14387: 2021                       | Ademhalingsbeschermingsmiddelen – Gasfilter(s) en combinatiefilter(s) – Eisen, beproeving, merken  |
| NEN-EN 14593-1: 2018                     | Ademhalingsbeschermingsmiddelen – Slangentoestel voorzien van een ademhalingsautomaat – Deel 1: Toestel met een volgelaatsmasker – Eisen, beproeving, merken                                 |
| NEN-EN 14594: 2018                       | Ademhalingsbeschermingsmiddelen – Slangentoestel geschikt voor continu stromende samengeperste ademplucht – Eisen, beproeving, merken  |
| NEN-ISO 16900-1: 2019                    | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 1: Bepaling van de inwaartse lekkage  |
| NEN-ISO 16900-2: 2017                    | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 2: Bepaling van de ademhalingsweerstand   |
| ISO 16900-3: 2012                        | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 3: Bepaling van het doordringingsvermogen van een deeltjesfilter  |
| NEN-ISO 16900-4: 2011                    | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 4: Bepaling van de gasfiltercapaciteit, migratie, desorptie en koolmonoxide dynamisch testen            |
| NEN-ISO 16900-6: 2015                    | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 6: Mechanische weerstand / sterkte van componenten en verbindingen                                      |
| NEN-ISO 16900-7: 2020                    | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 7: Praktische prestatiebeproevingmethoden   |
| NEN-ISO 16900-8: 2015                    | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 8: Metingen van RPD luchtvolumestromen van ondersteunde RPD filtering                                   |

| <b>B1 Respiratory protective devices</b> |  |
|--|--|
| NEN-ISO 16900-9: 2015                    | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 9: Bepaling van het koolstofdioxidegehalte van geïnhaleerde lucht   |
| NEN-ISO 16900-10: 2015                   | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 10: Bestandheid tegen ontbranding, vlam, stralingswarmte en warmte  |
| NEN-ISO 16900-11: 2013                   | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 11: Bepaling van het gezichtsveld   |
| NEN-ISO 16900-12: 2016                   | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 12: Bepaling van de ademhalingsdruk tijdens het ademen bij gemiddelde werkinspanning en bij piekbelasting   |
| NEN-ISO 16900-13: 2015                   | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 13: Ademhalingsbeschermingsmiddelen welke gebruik maken van geregeneerd ademluchtgas en bij specifieke toepassing van ademvluchttoestellen in de mijnen |
| NEN-ISO 16900-14: 2020                   | Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 14: Meting van het geluidsniveau  |
| NEN-EN-ISO 16972: 2020                   | Ademhalingsbeschermingsmiddelen – Woordenlijst en grafische symbolen   |
| NVN-ISO/TS 16973: 2016                   | Ademhalingsbeschermingsmiddelen – Indeling voor ademhalingsbeschermingsmiddelen  |
| NVN-ISO/TS 16975-1: 2016                 | Ademhalingsbeschermingsmiddelen – Keuze, gebruik en onderhoud – Deel 1: Vastlegging en implementatie van een ademhalingsbeschermingsprogramma  |
| NVN-ISO/TS 16975-2: 2016                 | Ademhalingsbeschermingsmiddelen – Keuze, gebruik en onderhoud – Deel 2: Beknopte leidraad voor het vaststellen en implementeren van een ademhalingsbeschermingsprogramma   |
| NEN-ISO 16975-3: 2017                    | Ademhalingsbeschermingsmiddelen – Keuze, gebruik en onderhoud – Deel 3: Methode voor het testen van de pasvorm   |
| NEN-ISO 16975-4: 2022                    | Respiratory protective devices - Selection, use and maintenance - Part 4: Selection and usage guideline for respiratory protective devices under pandemic/epidemic/outbreak of infectious respiratory disease                                |
| NVN-ISO/TS 16976-1: 2015                 | Ademhalingsbeschermingsmiddelen – Menselijke factoren – Deel 1: Metabolische waarden en de ademstroomwaarden   |
| NPR-ISO/TS 16976-2: 2015                 | Ademhalingsbeschermingsmiddelen – Menselijke factoren – Deel 2: Antropometrie  |
| NVN-ISO/TS 16976-3: 2019                 | Ademhalingsbeschermingsmiddelen – Menselijke factoren – Deel 3: Fysiologische reacties en beperkingen van zuurstof en beperkingen van kooldioxide in de ademhalingsomgeving  |
| NVN-ISO/TS 16976-4: 2019                 | Ademhalingsbeschermingsmiddelen – Menselijke factoren – Deel 4: Werking van ademhaling en ademhalingsweerstand: Fysiologisch limiet  |
| ISO/TS 16976-5: 2020                     | Ademhalingsbeschermingsmiddelen – Menselijke factoren – Deel 5: Thermische effecten  |
| NPR-ISO/TS 16976-6: 2014                 | Ademhalingsbeschermingsmiddelen – Menselijke factoren – Deel 6: Psycho-fysiologische effecten  |
| NVN-ISO/TS 16976-7: 2020                 | Ademhalingsbeschermingsmiddelen – Menselijke factoren – Deel 7: Gehoor en spraak   |
| NPR-ISO/TS 16976-8: 2013                 | Ademhalingsbeschermingsmiddelen – Menselijke factoren – Deel 8: Ergonomische factoren  |
| NEN-ISO 17420-1: 2021                    | Ademhalingsbeschermingsmiddelen – Prestatie-eisen – Deel 1: Algemeen   |
| ISO 17420-2: 2021                        | Ademhalingsbeschermingsmiddelen – Prestatie-eisen – Deel 2: Eisen voor RPD-filtering   |
| NEN-ISO 17420-3: 2012                    | Ademhalingsbeschermingsmiddelen – Prestatie-eisen – Deel 3: Schroefdraadaansluiting  |
| NEN-ISO 17420-4: 2021                    | Ademhalingsbeschermingsmiddelen – Prestatie-eisen – Deel 4: Eisen voor geleverde inhaleerbaar gas voor RPD   |
| DIN 58620-02: 2007                       | Atemschutzgeräte - Gasfilter und Kombinationsfilter zum Schutz gegen Kohlenstoffmonoxid - Anforderungen, Prüfung, Kennzeichnung  |
| DIN 58621-10: 2011                       | Atemschutzgeräte - Reaktorfilter zum Schutz gegen radioaktives Methyliodid und radioaktive Partikel - Anforderungen, Prüfung, Kennzeichnung  |

| <b>B2 Non-Occupational Health and Safety Breath-RPE</b> |  |
|---|--|
| NEN-EN 14683: 2019+C1:2019 en                           | Medische gezichtsmaskers - Eisen en beproevingsmethoden  |
| NEN-spec 1-1:2021-10-15 nl                              | Mondkapjes voor publiek gebruik - Deel 1: Aanbevelingen voor ontwerp, gebruik en onderhoud in het kader van COVID-19 |
| NEN-spec 1-2:2021-10-15 nl                              | Mondkapjes voor publiek gebruik - Deel 2: Eisen voor fabrikanten en importeurs in het kader van COVID-19             |

| <b>B3 Standards for breathing apparatus – outside the scope of this Directive</b> |   |
|---|---|
| NEN-EN 402: 2003  | <i>Ademhalingsbeschermingsmiddelen – Door de longen aangestuurde onafhankelijke persluchtademhalingstoestellen met een volgelaatsmasker of mondstukgarrituur voor vluchtdoeleinden – Eisen, beproeving, merken</i>                                  |
| NEN-EN 403: 2004  | <i>Ademhalingsbeschermingsmiddelen voor vluchtdoeleinden – Filterende toestellen met kap voor vluchtdoeleinden bij brand – Eisen, beproeving, merken</i>  |
| NEN-EN 404: 2005  | <i>Ademhalingsbeschermingsmiddelen voor vluchtdoeleinden - Zelfredmiddel met filter tegen koolmonoxide met een mondstukgarrituur</i>  |
| NTA 8002: 2000nl  | <i>Beschermende maskers voor reddingsactiviteiten – Prestatie-eisen en beproevingen</i>   |
| NEN-EN 1146: 2005   | <i>Ademhalingsbeschermingsmiddelen – Onafhankelijke ademluchttoestellen met een kap voor vluchtdoeleinden – Eisen, beproeving, merken</i>   |
| NEN-EN 13794: 2002  | <i>Ademhalingsbeschermingsmiddelen – Onafhankelijke kringloopademhalingstoestellen voor vluchtdoeleinden – Eisen, beproeving, merken</i>  |
| NEN-ISO 16900-13: 2015  | <i>Ademhalingsbeschermingsmiddelen – Beproevingmethoden en beproevingsapparatuur – Deel 13: Ademhalingsbeschermingsmiddelen welke gebruik maken van geregeneerd ademluchtgas en bij specifieke toepassing van ademvluchttoestellen in de mijnen</i> |

## ANNEX C: Odour thresholds

Sources:

- AIHA: Odor Thresholds for Chemicals with Established Health Standards, 2nd Edition, 2013.
- RIVM: Table of Health-Based Assessment Values and Odor Thresholds for Soil Remediation (lowest median; version April 21, 2023); <https://www.rivm.nl/ggd-richtlijn-mmk-bodemsanering/overzichten-begrippenlijst/tabel-toetsingswaarden-geurdrempels>

| Name                    | CAS-number   | Odor Threshold in ppm | Odor Character                               | Source |
|-------------------------|--|-----------------------|--|--------|
| Acetaldehyde            | 75-07-0  | 0.0015 – 1000         | Pungent, fruity, suffocating, fresh, gree    | AIHA   |
| Acetic acid             | 64-19-7  | 0.0004 – 204          | Pungent, vinegar                             | AIHA   |
| Acetic anhydride        | 108-24-7   | 0.12 – 0.36           | Sour, acid                                   | AIHA   |
| Aceton                  | 67-64-1  | 0.40 – 11745          | Sweet, fruity, etherous                      | AIHA   |
| Acetonitrile            | 75-05-8  | 13 – 1161             | Etherish                                     | AIHA   |
| Acetophenone            | 98-86-2  | 0.00024 – 0.59        | Sweet, almond, pungent, oranges, river water | AIHA   |
| Acetylacetone           | 123-54-6   | 0.0098 – 0.0195       | –  | AIHA   |
| Acetylene               | 74-86-2  | 226 – 2584            | Gassy, garlic                                | AIHA   |
| Acrylaldehyde           | 107-02-8   | 0.0036 – 1.8          | Pungent                                      | AIHA   |
| Acrylic acid            | 79-10-7  | 0.092 – 1.0           | Rancid, plastic, sweet                       | AIHA   |
| Acrylonitrile           | 107-13-1   | 1.6 – 22              | Onion, garlic                                | AIHA   |
| Allyl isothiocyanate    | 57-06-7  | 0.0091 – 1.97         | Irritating                                   | AIHA   |
| Allyl alcohol           | 107-18-6   | 0.51 – 35             | Mustard                                      | AIHA   |
| Ammonia                 | 7664-41-7  | 0.043 – 60.3          | Pungent, irritating                          | AIHA   |
| Aniline                 | 62-53-3  | 0.012 – 10            | Pungent, oily, empyreumatic                  | AIHA   |
| Arsine                  | 7784-42-1  | <1.0                  | Garlic                                       | AIHA   |
| Aziridine               | 151-56-4   | 0.71 – 2              | Ammonia                                      | AIHA   |
| Benzaldehyde            | 100-52-7   | 0.0015 – 783          | Bitter almond, fruit, vanilla                | AIHA   |
| Benzene                 | 71-43-2  | 0.47 – 313            | Aromatic, sweet, solvent, empyreumatic       | AIHA   |
| Benzene                 | 71-43-2  | 1.57 – 25.04          |  | RIVM   |
| Benzenethiol            | 108-98-5   | 0.00003 – 0.00027     | Putrid                                       | AIHA   |
| Benzoquinone{p-}        | 106-51-4   | 0.011 – 0.10          | Pungent                                      | AIHA   |
| Benzoyl chloride        | 98-88-4  | 0.0021 – 0.0063       | Pungent                                      | AIHA   |
| Benzoylacetate          | 140-11-4   | 0.00016 – 22          | Pears, plastic, etherous, anise              | AIHA   |
| Benzyl chloride         | 100-44-7   | 0.041 – 0.046         | Pungent                                      | AIHA   |
| Biphenyl                | 92-52-4  | 0.00052 – 0.0095      | Pleasant, butter-like                        | AIHA   |
| Boron trifluoride       | 7637-07-2  | 1.5                   | Pungent                                      | AIHA   |
| Bromoform               | 75-25-2  | 0.19 – 15             | Chloroform, sweet, suffocating               | AIHA   |
| Bromine                 | 7726-95-6  | <0.0099 – 0.99        | Alliaceous, sharp, irritating                | AIHA   |
| Butane (all isomers)    | 106-97-8, 75-28-5  | 0.421 – 5048          | Natural gas                                  | AIHA   |
| Butanedione             | 431-03-8   | 0.000002 – 2.9        | Pleasant, buttery                            | AIHA   |
| Butanethiol             | 109-79-5   | 0.0000027 – 4.9       | Skunk  | AIHA   |
| Butadiene{1,3-}         | 106-99-0   | 0.099 – 76            | Aromatic, rubber                             | AIHA   |
| Butanol{1-}             | 71-36-3  | 0.0033 – 990          | Sweet, malty, alcohol, medicinal             | AIHA   |
| Butanol{2-}             | 78-92-2  | 0.043 – 94            | Sweet, malty alcohol                         | AIHA   |
| Butanol{t-}             | 75-65-0  | 3.3 – 957             | Sweet alcohol                                | AIHA   |
| Butanone{2-}            | 78-93-3  | 0.07 – 339            | Sweet, sharp                                 | AIHA   |
| Butene (all isomers)    | 106-98-9, 107-01-7, 590-18-1, 624-64-6, 25167-67-3, 115-11-7 | 0.362 – 2126          | Petroleum                                    | AIHA   |
| Butenone                | 78-94-4  | 0.174                 | Pungent                                      | AIHA   |
| Butoxyethanol{2-}       | 111-76-2   | 0.08 – 0.35           | Sweet, ester, musty                          | AIHA   |
| Butoxyethyl acetate{2-} | 112-07-2   | 0.107 – 0.99          | Fruity                                       | AIHA   |
| Butyl acetate{iso-}     | 110-19-0   | 0.008 – 129           | Sweet, ester, medicinal                      | AIHA   |
| Butyl acetate {n-}      | 123-86-4   | 0.00013 – 368         | Sweet, banana                                | AIHA   |
| Butyl acetate {sec-}    | 105-46-4   | 0.0025 – 4.76         | Fruity                                       | AIHA   |

| Name                                       | CAS-number                             | Odor Threshold in ppm | Odor Character   | Source |
|--|--|-----------------------|--|--------|
| Butyl acetate {tert-}                      | 540-88-5                               | 0.008 – 1.31          | Mild   | AIHA   |
| Butyl acrylate{n-}                         | 141-32-2                               | 0.00029 – 0.101       | Sweet, rancid, plastic   | AIHA   |
| Butylamine{n-}                             | 109-73-9                               | 0.08 – 13.9           | Sour ammonical   | AIHA   |
| Butyl-L-lactate{n-}                        | 138-22-7                               | 0.0000000049          | Mild   | AIHA   |
| Butyl toluene{p-tert-}                     | 98-51-1                                | <5.031                | Gasoline   | AIHA   |
| Butyraldehyde                              | 123-72-8                               | 0.0003 – 5.09         | Pungent  | AIHA   |
| Camphor (synthetic)                        | 76-22-2                                | 0.0026 - 7.2          | Camphorous   | AIHA   |
| Carbon dioxide                             | 124-38-9                               | 39000 – 600136        | –  | AIHA   |
| Carbon disulphide                          | 75-15-0                                | 0.016 – 32            | Vegetable, sulfide, medicinal                                    | AIHA   |
| Carbon tetrachloride / Tetra chloromethane | 56-23-5                                | 1.68 – 720            | Sweet, ethereal, dry cleaner, aromatic                           | AIHA   |
| Carbonyl sulphide                          | 463-58-1                               | 0.057 – 0.102         | Unpleasant   | AIHA   |
| Chlorine                                   | 7782-50-5                              | 0.021 – 4.9           | Suffocating, sharp, bleach                                       | AIHA   |
| Chlorine dioxide                           | 10049-04-4                             | 15                    | Chlorine   | AIHA   |
| Chloroacetic acid                          | 79-11-8                                | 0.013 – 0.155         | –  | AIHA   |
| Chloroacetophenone{2-}                     | 532-27-4                               | 0.016 - 0.111         | Fruity   | AIHA   |
| Chlorobenzene                              | 108-90-7                               | 0.087 - 13            | Almond-like, shoe polish   | AIHA   |
| Chlorodifluoromethane (FC22)               | 75-45-6                                | 200192                | Ethereal   | AIHA   |
| Chloroethane                               | 75-00-3                                | 3.8 – 379             | Pungent  | AIHA   |
| Chloroethane                               | 75-00-3                                | 3.7                   |  | RIVM   |
| Chloroethanol{2-}                          | 107-07-3                               | 0.36                  | Ethereal   | AIHA   |
| Chloroform                                 | 67-66-3                                | 0.102 – 1,413         | Sweet, etherous, suffocating                                     | AIHA   |
| Chloroprene{3-}                            | 107-05-1                               | 0.48 – 5.9            | Pungent  | AIHA   |
| Chloroprene{beta-}                         | 126-99-8                               | 0.11 – 276            | Rubber   | AIHA   |
| Chlorotoluene{o-}                          | 95-49-8                                | 0.18 – 0.270          | Aromatic   | AIHA   |
| Citral                                     | 5392-40-5                              | 0.000024 – 0.032      | Lemon, flowery, citrus   | AIHA   |
| Cresol (all isomers)                       | 1319-77-3, 95-48-7, 108-39-4, 106-44-5 | 0.00005 – 0.0090      | Creosote, phenol, irritating, smoky, empyreumatic, burnt plastic | AIHA   |
| Cresol (sum)                               | 1319-77-3 o: 95-48-7 p: 93-51-6        | 0.0001 – 0.0022       |  | RIVM   |
| Crotonaldehyde                             | 4170-30-3, 123-73-9                    | 0.02 – 0.59           | Pungent  | AIHA   |
| Cumene                                     | 98-82-8                                | 0.008 – 1.3           | Sharp  | AIHA   |
| Cyanogen chloride                          | 506-77-4                               | 0.994                 | Acid   | AIHA   |
| Cyclohexane                                | 110-82-7                               | 0.52 – 784            | Pungent  | AIHA   |
| Cyclohexanol                               | 108-93-0                               | 0.058 – 0.491         | Camphorous   | AIHA   |
| Cyclohexanone                              | 108-94-1                               | 0.052 – 219           | Sweet, sharp   | AIHA   |
| Cyclohexene                                | 110-83-8                               | 0.18                  | Sweet  | AIHA   |
| Cyclohexylamine                            | 108-91-8                               | 2.42                  | Ammonia  | AIHA   |
| Cyclopentadiene{1,3-}                      | 542-92-7                               | 1.8                   | Terpene-like, pine, fruit  | AIHA   |
| Decaborane                                 | 17702-41-9                             | 0.06                  | Pungent  | AIHA   |
| Dec-1-ene                                  | 872-05-9                               | 6.45                  | Pleasant   | AIHA   |
| Diacetone alcohol                          | 123-42-2                               | 0.27 – 13             | Sweet  | AIHA   |
| Diallyl amine                              | 124-02-7                               | 2                     | Disagreeable   | AIHA   |
| Diaminoethane{1,2-}                        | 107-15-3                               | 1.3 – 4.5             | Ammonia  | AIHA   |
| Diborane                                   | 19287-45-7                             | 1.8 – 3.5             | Repulsive  | AIHA   |
| Dibromo-3-chloropropane{1,2-}              | 96-12-8                                | 0.01 – 0.031          | Irritating   | AIHA   |
| Dibromoethane{1,2-}                        | 106-93-4                               | <10                   | Sweet  | AIHA   |
| Dibutyl phthalate                          | 84-74-2                                | 0.023                 | –  | AIHA   |
| Dichloroacetic acid                        | 79-43-6                                | 0.044                 | –  | AIHA   |
| Dichlorobenzene{1,2-}                      | 95-50-1                                | 0.02 – 50             | Camphor  | AIHA   |
| Dichlorobenzene{1,4-}                      | 106-46-7                               | 0.121 – 15            | Camphor, mothballs   | AIHA   |
| Dichlorodifluoromethane                    | 75-71-8                                | 199790                | Ethereal   | AIHA   |
| Dichloroethane{1,1-}                       | 75-34-3                                | 49 – 1359             | Chloroform, aromatic   | AIHA   |
| Dichloroethane{1,1-}                       | 75-34-3                                | 49.41 – 148.24        |  | RIVM   |
| Dichloroethane{1,2-}                       | 107-06-2                               | 4.3 – 988             | Sweet  | AIHA   |
| Dichloroethylene{cis 1,2-}                 | 156-59-2                               | 0.08 – 10.09          |  | RIVM   |

| Name  | CAS-number                               | Odor Threshold in ppm | Odor Character                                    | Source |
|---|--|-----------------------|---|--------|
| Dichloroethylene{trans 1,2-}                | 156-60-5                                 | 0.08 – 10.09          |   | RIVM   |
| Dichloroethylene{1,2-} (all isomers)        | 156-60-5, 156-59-2, 540-59-0             | 277                   | Pleasant  | AIHA   |
| Dichlorophenol{2,4-}                        | 120-83-2                                 | 0.000041              | Medicinal, phenolic, leather-like, fish sauce     | AIHA   |
| Dichloropropane{1,2-}                       | 78-87-5                                  | 0.26 – 8.66           | Sweet   | AIHA   |
| Dichloropropene{1,3-}                       | 542-75-6                                 | <0.99                 | Sweet, pungent                                    | AIHA   |
| Dicyan                                      | 460-19-5                                 | >500                  | Almonds   | AIHA   |
| Dicyclopentadiene                           | 77-73-6                                  | 0.00019 – 0.02        | Sweet, sharp                                      | AIHA   |
| Diethanolamine                              | 111-42-2                                 | 0.279                 | Ammonia, amine, rotten fish                       | AIHA   |
| Diethylamine                                | 109-89-7                                 | 0.0033 – 14.3         | Musty, fishy, amine                               | AIHA   |
| Diethylaminoethanol{2-}                     | 100-37-8                                 | 0.01 – 0.25           | Amine, sharp, ammoniacal                          | AIHA   |
| Diethylbenzenes (all isomers)               | 25340-17-4, 135-01-3, 105-05-5, 141-93-5 | 0.00038 – 0.071       | –   | AIHA   |
| Diethyl ether                               | 60-29-7                                  | 0.165 – 1924          | Anesthetic, etherous                              | AIHA   |
| Diethylene glycol monoethyl ether           | 111-90-0                                 | <0.219 – 1.09         | Mild, pleasant                                    | AIHA   |
| Diethyl ketone                              | 96-22-0                                  | 0.85 – 14             | Acetone, fingernail polish remover                | AIHA   |
| Diethyl phthalate{p-}                       | 84-66-2                                  | 0.036 – 0.363         | –   | AIHA   |
| Dihydrogen selenide                         | 7783-07-5                                | <0.3                  | Garlic  | AIHA   |
| Diisopropylamine                            | 108-18-9                                 | 0.014 – 4.2           | Amine, fishy                                      | AIHA   |
| Diisopropyl ether                           | 108-20-3                                 | 0.017 – 0.053         | Sweet   | AIHA   |
| Dimethylacetamide{N,N-}                     | 127-19-5                                 | 48                    | Faint, ammonia                                    | AIHA   |
| Dimethylamine                               | 124-40-3                                 | 0.00076 – 4.2         | Ammoniacal, rotten fish                           | AIHA   |
| Dimethylaniline{N,N-}                       | 121-69-7                                 | 0.001 – 0.2           | Oily  | AIHA   |
| Dimethyl benzyl hydroperoxide{alpha,alpha-} | 80-15-9                                  | 0.0048                | Sharp, irritating                                 | AIHA   |
| Dimethylbutyl acetate{1,3-}                 | 108-84-9                                 | <0.068 – 0.39         | Banana, pear, fruity                              | AIHA   |
| Dimethyl disulfide                          | 624-92-0                                 | 0.00029 – 1.45        | Garlic, putrid, asparagus                         | AIHA   |
| Dimethyl ether                              | 115-10-6                                 | 161 – 228             | Ethereal  | AIHA   |
| Dimethylformamide                           | 68-12-2                                  | 0.047 – 100           | Fishy   | AIHA   |
| Dimethylheptanon-4{2,6-}                    | 108-83-8                                 | <0.103 – 1.6          | Peppermint  | AIHA   |
| Dimethylhydrazine{1,1-}                     | 57-14-7                                  | <0.31 – 14            | Fishy   | AIHA   |
| Dimethylnitrosoamine                        | 62-75-9                                  | 0.0079 – 0.013        | Faint   | AIHA   |
| Dimethylsulfide                             | 75-18-3                                  | 0.00012 – 8.11        | Disagreeable, asparagus, putrid                   | AIHA   |
| Di-n-butylamine                             | 111-92-2                                 | 0.079 – 0.770         | Amine   | AIHA   |
| Dinitro-o-cresol{4,6-}                      | 534-52-1                                 | 0.00049 - 0.00259     | –   | AIHA   |
| Dioxane{1,4-}                               | 123-91-1                                 | 0.8 – 2609            | Sweet alcohol                                     | AIHA   |
| Dioxolan{1,3-}                              | 646-06-0                                 | 16.8 – 63.4           | –   | AIHA   |
| Diphenylamine                               | 122-39-4                                 | 0.022 – 0.188         | Floral  | AIHA   |
| Dodecanethiol{1-}                           | 112-55-0                                 | 0.0000011 – 0.000097  | Skunk   | AIHA   |
| Epichlorohydrin                             | 106-89-8                                 | 0.08 – 12             | Chloroform  | AIHA   |
| Epoxypropane{1,2-}                          | 75-56-9                                  | 10 – 199              | Sweet   | AIHA   |
| Ethane                                      | 74-84-0                                  | 20328 – 730973        | –   | AIHA   |
| Ethane-1,2-diol                             | 107-21-1                                 | 5.12                  | –   | AIHA   |
| Ethanethiol                                 | 75-08-1                                  | 0.0000087 – 18        | Rotten cabbage                                    | AIHA   |
| Ethanol                                     | 64-17-5                                  | 0.09 – 40334          | Vinous, alcohol                                   | AIHA   |
| Ethanolamine                                | 141-43-5                                 | 2.6 – 24              | Ammonia   | AIHA   |
| Ethoxyethanol{2-}                           | 110-80-5                                 | 0.3 – 49              | Sweet, musty                                      | AIHA   |
| Ethoxyethyl acetate{2-}                     | 111-15-9                                 | 0.048 – 0.13          | Sweet, ester                                      | AIHA   |
| Ethyl acetate                               | 141-78-6                                 | 0.09 – 190            | Fruity, sweet, fingernail polish, etherous        | AIHA   |
| Ethyl acrylate                              | 140-88-5                                 | 0.0000066 – 0.0032    | Sweet, ester, plastic, alcohol, sharp, ammoniacal | AIHA   |
| Ethylamine                                  | 75-04-7                                  | 0.027 – 3.5           | Ammonia   | AIHA   |
| Ethylbenzene                                | 100-41-4                                 | <0.002 – 18           | Oily, solvent                                     | AIHA   |
| Ethylbenzene                                | 100-41-4                                 | 2.0 – 20.7            |   | RIVM   |

| Name                                    | CAS-number  | Odor Threshold in ppm   | Odor Character                          | Source |
|---|---|-------------------------|---|--------|
| Ethyl bromide                           | 74-96-4   | 2.7 – 3.6               | Ethereal                                | AIHA   |
| Ethylene                                | 74-85-1   | 17 – 1029               | Grassy                                  | AIHA   |
| Ethylene oxide                          | 75-21-8   | 0.82 – 690              | Sweet, olefinic                         | AIHA   |
| Ethyl formate                           | 109-94-4  | 2.7 – 30                | Aromatic                                | AIHA   |
| Ethylidene norbornene                   | 16219-75-3  | 0.007 – 0.08            | Turpentine                              | AIHA   |
| Ethylmorpholine{n-}                     | 100-74-3  | 0.085 – 0.25            | Ammonia                                 | AIHA   |
| Ethyl tertiary butyl ether (ETBE)       | 637-92-3  | 0.013                   |   | RIVM   |
| Fluorine                                | 7782-41-4   | 0.097 – 0.19            | Pungent                                 | AIHA   |
| Formaldehyde                            | 50-00-0   | 0.027 – 9.770           | Pungent                                 | AIHA   |
| Formaldehyde                            | 50-00-0   | 0.024 – 8.140           |   | RIVM   |
| Formic acid                             | 64-18-6   | 0.52 – 340              | Sharp                                   | AIHA   |
| Furaldehyde{2-}                         | 98-01-1   | 0.002 – 0.713           | Bread, almond                           | AIHA   |
| Furan                                   | 110-00-9  | 10.06                   | Strong                                  | AIHA   |
| Furfuryl alcohol                        | 98-00-0   | 8                       | Sweet, ether, alcohol                   | AIHA   |
| Glutaraldehyde                          | 111-30-8  | 0.00037 – 0.039         | –                                       | AIHA   |
| Halothane                               | 151-67-7  | 33                      | Chloroform                              | AIHA   |
| Heptane (all isomers)                   | 142-82-5,<br>590-35-2,<br>565-59-3,<br>108-08-7,<br>591-76-4,<br>589-34-4 | 0.41 – 732              | Gasoline                                | AIHA   |
| Heptanone{2-}                           | 110-43-0  | 0.00075 – 0.71          | Sweet, mushroom                         | AIHA   |
| Hexachlorocyclopentadiene               | 77-47-4   | 0.15                    | Pungent                                 | AIHA   |
| Hexamethylenediamine                    | 124-09-4  | 0.00067                 | –                                       | AIHA   |
| Hexamethylene diisocyanate              | 822-06-0  | 0.005 – 0.01            | –                                       | AIHA   |
| Hexane (all isomers, except Hexane{n-}) | 107-83-5, 96-14-0, 75-83-2, 79-29-8                                       | 0.426 – 20              | Gasoline                                | AIHA   |
| Hexane{n-}                              | 110-54-3  | 1.50 – 248              | Gasoline                                | AIHA   |
| Hexanol{1-}                             | 111-27-3  | 0.0024 – 16             | Green grass, plastic                    | AIHA   |
| Hexanolactam{1,6-}                      | 105-60-2  | 0.065                   | Mild                                    | AIHA   |
| Hexan-2-one                             | 591-78-6  | 0.024 – 1.15            | Sweet, paint                            | AIHA   |
| Hexene{1-}                              | 592-41-6  | 0.139                   | Petroleum                               | AIHA   |
| Hydrazine                               | 302-01-2  | 3.0 – 4.0               | Ammonia                                 | AIHA   |
| Hydrogen chloride                       | 7647-01-0   | 0.06 – 10               | Sharp, irritating                       | AIHA   |
| Hydrogen cyanide                        | 74-90-8   | 0.009 – 5.43            | Almonds                                 | AIHA   |
| Hydrogen fluoride                       | 7664-39-3   | 0.04                    | Highly corrosive, irritating            | AIHA   |
| Hydrogen sulphide                       | 7783-06-4   | 0.00004 – 1.4           | Rotten eggs                             | AIHA   |
| Indene                                  | 95-13-6   | 0.0027 – 0.0042         | –                                       | AIHA   |
| Iodine                                  | 7553-56-2   | 0.973                   | Sharp, alliaceous                       | AIHA   |
| Iodoform                                | 75-47-8   | 0.000019 – 1.12         | Chemical, etherish                      | AIHA   |
| Isoamyl alcohol                         | 123-51-3  | 0.00169 – 1.75          | Sweet, malty, rancid, rubber            | AIHA   |
| Isobutyraldehyde                        | 78-84-2   | 0.00034 – 0.139         | Pungent                                 | AIHA   |
| Isooctyl alcohol (mixture of isomers)   | 26952-21-6,<br>60435-70-3   | 0.0092 – 0.049          | Faint, pleasant                         | AIHA   |
| Isopentyl acetate                       | 123-92-2  | 0.00075 – 366           | Banana, fresh                           | AIHA   |
| Isoprene                                | 78-79-5   | 0.047 – 3.59            | Aromatic                                | AIHA   |
| Isopropyl acetate                       | 108-21-4  | 0.160 – 41              | Fruity                                  | AIHA   |
| Isopropyl amine                         | 75-31-0   | 0.025 – 0.70            | Ammoniacal, amine                       | AIHA   |
| Limonene                                | 138-86-3  | 0.0018 – 0.31           | Lemon, plastic, citrus, rubber, terpeny | AIHA   |
| Maleic anhydride                        | 108-31-6  | 0.25 – 0.32             | Acrid                                   | AIHA   |
| Mercaptoacetic acid                     | 68-11-1   | 0.00021                 | Unpleasant                              | AIHA   |
| Mercaptoethanol{2-}                     | 60-24-2   | 0.075                   | –                                       | AIHA   |
| Mecrilate                               | 137-05-3  | 0.99 – 2.97             | –                                       | AIHA   |
| Mesityl oxide                           | 141-79-7  | 0.017 – 12              | Sweet                                   | AIHA   |
| Methane                                 | 74-82-8   | 2896197                 | –                                       | AIHA   |
| Methanethiol                            | 74-93-1   | 0.00000000000051 – 0.56 | Rotten cabbage, garlic                  | AIHA   |
| Methacrylic acid                        | 79-41-4   | 0.54 – 2.84             | Pungent                                 | AIHA   |

| Name   | CAS-number                           | Odor Threshold in ppm | Odor Character                              | Source |
|--|--------------------------------------|-----------------------|---|--------|
| Methacrylonitrile  | 126-98-7                             | 2.95 – 6.9            | –   | AIHA   |
| Methanol   | 67-56-1                              | 3.05 – 198686         | Sour, sweet, alcohol                        | AIHA   |
| Methoxy ethanol{2-}  | 109-86-4                             | <0.096 – 90           | Sweet alcohol                               | AIHA   |
| Methoxyethyl acetate{2-}   | 110-49-6                             | 0.33 – 0.64           | Sweet, ester                                | AIHA   |
| Methoxy-1-methylethyl acetate{2-}                                  | 108-65-6                             | 0.0029 – 0.13         | –   | AIHA   |
| Methoxypropan-2-ol{1-}   | 107-98-2                             | 8.39 – 33             | Etherish, ammonia                           | AIHA   |
| Methyl acetate   | 79-20-9                              | 0.17 – 2,848          | Fruity                                      | AIHA   |
| Methyl acrylate  | 96-33-3                              | 0.003 – 0.025         | Plastic, sharp, airplane glue               | AIHA   |
| Methylamine  | 74-89-5                              | 0.00075 - 4.8         | Fishy                                       | AIHA   |
| Methylaniline{N-}  | 100-61-8                             | 1.6 – 2.0             | –   | AIHA   |
| Methylbutanone{3-}   | 563-80-4                             | 0.51 – 4.8            | Sweet, sharp                                | AIHA   |
| Methylbutyl acetate{2-}  | 624-41-9                             | 0.026 – 0.039         | –   | AIHA   |
| Methyl chloride  | 74-87-3                              | >10                   | Sweet, etherish                             | AIHA   |
| Methylcyclohexane  | 108-87-2                             | 0.149                 | Petroleum                                   | AIHA   |
| Methylcyclohexanone{o-}  | 583-60-8                             | 0.181                 | Acetone                                     | AIHA   |
| Methylene chloride/<br>Dichloromethane                             | 75-09-2                              | 1.2 – 440             | Sweet                                       | AIHA   |
| Methylenediphenyl diisocyanate{4,4'-}                              | 101-68-8                             | 0.39                  | –   | AIHA   |
| Methyl formate   | 107-31-3                             | 67 – 2809             | Ethereal                                    | AIHA   |
| Methylheptan-3-one{5-}   | 541-85-5                             | 5.9                   | Solvent, sharp                              | AIHA   |
| Methylhexan-2-one{5-}  | 110-12-3                             | 0.0021 – 0.135        | Sweet, sharp                                | AIHA   |
| Methylisocyanate   | 624-83-9                             | 2.14                  | –   | AIHA   |
| Methyl methacrylate  | 80-62-6                              | 0.014 – 0.66          | Plastic, sharp                              | AIHA   |
| Methylnaphthalene{2-}  | 91-57-6                              | 0.00069               | –   | AIHA   |
| Methylpentane-2,4-diol{2-}   | 107-41-5                             | 3.93                  | Mild, sweet                                 | AIHA   |
| Methylpentan-2-ol{4-}  | 108-11-2                             | 0.335 – 0.526         | –   | AIHA   |
| Methylpentan-2-one{4-}   | 108-10-1                             | 0.03 – 16             | Sweet, sharp                                | AIHA   |
| Methylpropan-1-ol{2-}  | 78-83-1                              | 0.01 – 165            | Sweet, fusel, musty, alcohol, rubber, latex | AIHA   |
| Methylpyridine{2-} &<br>Methylpyridine{3-} &<br>Methylpyridine{4-} | 109-06-8,<br>108-99-6,<br>108-89-4   | 0.0026 – 0.0236       | Strong, unpleasant                          | AIHA   |
| Methyl-2-pyrrolidone{1-}   | 872-50-4                             | 4.2 – 10              | Amine                                       | AIHA   |
| Monomethyl hydrazine   | 60-34-4                              | 1 – 3                 | Ammonia                                     | AIHA   |
| Morpholine   | 110-91-8                             | 0.011 – 0.070         | Fishy, amine                                | AIHA   |
| Naphthalene  | 91-20-3                              | 0.0019 – 1.02         | Tar, creosote, mothballs, empyreumatic      | AIHA   |
| Naphthalene  | 91-20-3                              | 0.0095 – 0.1500       |   | RIVM   |
| Naphthylamine{1-}  | 134-32-7                             | 0.024 – 0.050         | –   | AIHA   |
| Naphthylamine {2-}   | 91-59-8                              | 0.24 – 0.32           | –   | AIHA   |
| Nicotine   | 54-11-5                              | 0.0099                | –   | AIHA   |
| Nitric acid  | 7697-37-2                            | 0.27                  | Suffocating                                 | AIHA   |
| Nitrobenzene   | 98-95-3                              | 0.0004 – 29           | Almonds, shoe polish, pungent               | AIHA   |
| Nitrogen dioxide   | 10102-44-0                           | 0.058 – 0.5           | Bleach                                      | AIHA   |
| Nitromethane   | 75-52-5                              | 50                    | –   | AIHA   |
| Nitropropane{1-}   | 108-03-2                             | 7.7 – 140             | –   | AIHA   |
| Nitropropane{2-}   | 79-46-9                              | 4.94 – 288            | Fruity                                      | AIHA   |
| Nonane   | 111-84-2                             | 2.3 – 21              | Gasoline                                    | AIHA   |
| Octane (all isomers)   | 111-65-9,<br>540-84-1,<br>86290-81-5 | 0.66 – 235            | Gasoline, oil                               | AIHA   |
| Octanol{1-}  | 111-87-5                             | 0.0009 – 1.69         | Penetrating                                 | AIHA   |
| Octene{1-}   | 111-66-0                             | 0.001 – 206           | –   | AIHA   |
| Oxygen difluoride  | 7783-41-7                            | 0.0996                | Strong, peculiar                            | AIHA   |
| Ozone  | 10028-15-6                           | 0.0031 – 0.25         | Pungent, thunderstorm                       | AIHA   |
| Quinoline  | 91-22-5                              | 0.0057 – 5.3          | Peculiar                                    | AIHA   |
| Parathion-methyl   | 298-00-0                             | 0.0012                | Pungent                                     | AIHA   |
| Pentaborane  | 19624-22-7                           | 0.97                  | Pungent                                     | AIHA   |
| Pentane (all isomers)  | 78-78-4, 109-66-0, 463-82-           | 1.29 – 1147           | Sweet                                       | AIHA   |

| Name  | CAS-number  | Odor Threshold in ppm | Odor Character                               | Source |
|---|---|-----------------------|--|--------|
|   | 1   |                       |  |        |
| Pentanol (all isomers)                                  | 71-41-0,75-85-4, 75-84-3, 123-51-3, 137-32-6, 584-02-1, 598-75-4, 6032-29-7, 30899-19-5, 94624-12-1 | 0.0055 – 305          | –  | AIHA   |
| Pentanone{2-}   | 107-87-9  | 0.028 – 65            | Fingernail polish                            | AIHA   |
| Pentyl acetate  | 628-63-7  | 0.007 – 43            | Banana, etherous                             | AIHA   |
| Perchloryl fluoride                                     | 7616-94-6   | 14.58                 | Sweet  | AIHA   |
| Phenol  | 108-95-2  | 0.0045 – 1.95         | Medicinal, acid, ink, creosote, empyreumatic | AIHA   |
| Phenol  | 108-95-2  | 0.005 – 0.180         |  | RIVM   |
| Phenylpropene{2-}                                       | 98-83-9   | 0.02 – 49.7           | –  | AIHA   |
| Phosphine   | 7803-51-2   | 0.01 – 5              | Garlic                                       | AIHA   |
| Phosgene  | 75-44-5   | 0.12 – 5.7            | Hay like                                     | AIHA   |
| Phthalic anhydride                                      | 85-44-9   | 0.053                 | Choking                                      | AIHA   |
| Piperidine  | 110-89-4  | 0.14 – <2             | Pepper                                       | AIHA   |
| Propane   | 74-98-6   | 1497 – 19964          | Natural gas                                  | AIHA   |
| Propane-1,2-diol  | 57-55-6   | 5.14                  | –  | AIHA   |
| Propane-1,2-diyl dinitrate                              | 6423-43-4   | 0.236                 | Disagreeable                                 | AIHA   |
| Propanol{1-}  | 71-23-8   | <0.031 – 10172        | Sweet alcohol                                | AIHA   |
| Propanol{2-}  | 67-63-0   | 1.0 – 2197            | Sharp, rubbing alcohol                       | AIHA   |
| Propionaldehyde   | 123-38-6  | 0.001 – 101           | Fruity                                       | AIHA   |
| Propionic acid  | 79-09-4   | 0.00099 – 4.65        | Sour   | AIHA   |
| Propyl acetate  | 109-60-4  | 0.048 – 87            | Sweet, ester                                 | AIHA   |
| Propylene   | 115-07-1  | 10.1 – 99             | Gassy, aromatic                              | AIHA   |
| Pyridine  | 110-86-1  | 0.01 – 12             | Burnt, pungent, nauseating                   | AIHA   |
| Pyridine  | 110-86-1  | 0.003 – 0.280         |  | RIVM   |
| Styrene   | 100-42-5  | 0.0028 – 61           | Sharp, sweet                                 | AIHA   |
| Styrene   | 100-42-5  | 0.02 – 0.70           |  | RIVM   |
| Sulphur dioxide   | 7446-09-5   | 0.33 - 8              | Metallic                                     | AIHA   |
| Sulphur dioxide   | 7446-09-5   | 0.31 – 3.05           |  | RIVM   |
| Sulphur hexafluoride                                    | 2551-62-4   | 4017527               | –  | AIHA   |
| Sulphuric acid  | 7664-93-9, 8014-95-7  | 0.15                  | –  | AIHA   |
| Tert-butyl methyl ether (MTBE)                          | 1634-04-4   | 0.03 – 0.17           | Anesthetic                                   | AIHA   |
| Tert-butyl methyl ether (MTBE)                          | 1634-04-4   | 0.09 – 0.47           |  | RIVM   |
| Tetrabromoethane{1,1,2,2-}                              | 79-27-6   | <0.99                 | Camphor, pungent                             | AIHA   |
| Tetracarbonylnickel                                     | 13463-39-3  | 0.5 – 3               | Sooty  | AIHA   |
| Tetrachloroethane{1,1,2,2-}                             | 79-34-5   | 0.233 – 7.3           | Solvent                                      | AIHA   |
| Tetrachloroethylene (PER)                               | 127-18-4  | 0.767 – 71            | Etherish                                     | AIHA   |
| Tetrachloroethylene (PER)                               | 127-18-4  | 10000 – 100000        |  | RIVM   |
| Tetraethyl orthosilicate                                | 78-10-4   | 3.6 – 85              | Sweet alcohol                                | AIHA   |
| Tetrahydrofuran   | 109-99-9  | 0.092 – 61            | Ether  | AIHA   |
| Toluene   | 108-88-3  | 0.021 – 157           | Sour, burnt                                  | AIHA   |
| Toluene   | 108-88-3  | 0.2 – 5.3             |  | RIVM   |
| Toluene diisocyanate{2,4-} & Toluene diisocyanate{2,6-} | 584-84-9, 91-08-7   | 0.02 – 2              | –  | AIHA   |
| Toluidine{m-}   | 108-44-1  | 0.46 – 5.9            | Empyreumatic                                 | AIHA   |
| Toluidine{o-}   | 95-53-4   | 0.025 – 6.6           | Aromatic, amine, empyreumatic                | AIHA   |
| Toluidine{p-}   | 106-49-0  | 0.027 – 3.2           | Amine, empyreumatic                          | AIHA   |
| Trichloro acetic acid                                   | 76-03-9   | 0.24 – 0.37           | –  | AIHA   |
| Trichlorobenzene{1,2,4-}                                | 120-82-1  | 2.96                  | Aromatic                                     | AIHA   |
| Trichloroethane{1,1,1-}                                 | 71-55-6   | 0.97 – 715            | Sweet, etherish                              | AIHA   |
| Trichloroethane{1,1,1-}                                 | 71-55-6   | 16.5 – 165.0          |  | RIVM   |
| Trichloroethylene                                       | 79-01-6   | 0.5 – 167             | Ether, solvent                               | AIHA   |

| Name   | CAS-number                               | Odor Threshold in ppm | Odor Character   | Source |
|--|--|-----------------------|--|--------|
| Trichloroethylene                            | 79-01-6                                  | 0.1900 – 9.300        |  | RIVM   |
| Trichlorofluoromethane (FC11)                | 75-69-4                                  | 5 – 200057            | –  | AIHA   |
| Trichloronitromethane                        | 76-06-2                                  | 1.09                  | Chlorine   | AIHA   |
| Triethanolamine                              | 102-71-6                                 | >10                   | Mild, ammonia  | AIHA   |
| Triethylamine                                | 121-44-8                                 | 0.005 – 2.9           | Fishy, amine   | AIHA   |
| Trimethylamine                               | 75-50-3                                  | 0.00002 – 1.82        | Fishy, pungent   | AIHA   |
| Trimethylbenzene (all isomers)               | 95-63-6, 108-67-8, 526-73-8, 25551-13-7  | 0.006 – 2.4           | Aromatic   | AIHA   |
| Trimethylcyclohexanon-2{3,5,5-}              | 78-59-1                                  | 0.0003 – 0.19         | Sharp  | AIHA   |
| Trimethyl phosphite                          | 121-45-9                                 | 0.000099              | Pungent  | AIHA   |
| Turpentine, oil & Monoterpenes               | 80-56-8, 127-91-3, 13466-78-9, 8006-64-2 | 0.00006 – 19          | Turpentine, rosiny, pine tree, camphorous, fir needles | AIHA   |
| Valeraldehyde                                | 110-62-3                                 | 0.0004 – 4.97         | Sickening, rancid, decayed                             | AIHA   |
| Vanillin                                     | 121-33-5                                 | 0.00000016 – 0.0929   | Vanilla, caramel, sweet                                | AIHA   |
| Vinyl acetate                                | 108-05-4                                 | 0.12 – 0.4            | Sour, sharp  | AIHA   |
| Vinyl chloride                               | 75-01-4                                  | 203 – 356             | Sweet  | AIHA   |
| Vinyl chloride                               | 75-01-4                                  |                       |  | RIVM   |
| Vinylidene chloride (Dichloroethylene{1,1-}) | 75-35-4                                  | 50 – 1387             | Chloroform   | AIHA   |
| Vinylidene chloride (Dichloroethylene{1,1-}) | 75-35-4                                  | 190 - 496             |  | RIVM   |
| Xylene (all isomers)                         | 1330-20-7, 95-47-6, 108-38-3, 106-42-3   | 0.012 – 316           | Sweet, empyreumatic                                    | AIHA   |
| Xylene (sum)                                 | 1330-20-7                                | 400 – 8000            |  | RIVM   |