Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe
Table of Contents

Introduction.........................................................................................................................6

Risk factors included in the Workers’ Exposure Survey – background information by cancer risk factor 7

1. Acrylamide.......................................................................................................................7
   Use of acrylamide..............................................................................................................7
   Occupational exposure....................................................................................................7
   Health effects..................................................................................................................8
   EU and IARC classification ............................................................................................8
   Legislation .......................................................................................................................8

2. Arsenic (and compounds)...............................................................................................9
   Use of arsenic..................................................................................................................9
   Arsenic compounds .......................................................................................................9
   Occupational exposure..................................................................................................10
   Health effects................................................................................................................10
   EU and IARC classification ..........................................................................................10
   Legislation .....................................................................................................................11

3. Asbestos ........................................................................................................................12
   Use of asbestos...............................................................................................................12
   Occupational exposure..................................................................................................13
   Health effects................................................................................................................13
   EU and IARC classification ..........................................................................................13
   Legislation .....................................................................................................................14

4. Benzene ........................................................................................................................15
   Use of benzene ...............................................................................................................15
   Occupational exposure..................................................................................................15
   Health effects................................................................................................................16
   EU and IARC classification ..........................................................................................16
   Legislation .....................................................................................................................17

5. 1,3-Butadiene .................................................................................................................18
   Use of 1,3-butadiene......................................................................................................18
   Occupational exposure..................................................................................................18
   Health effects................................................................................................................18
   EU and IARC classification ..........................................................................................18
   Legislation .....................................................................................................................19

6. Cadmium (and compounds)............................................................................................20
   Use of cadmium.............................................................................................................20
   Cadmium compounds ..................................................................................................20
   Occupational exposure..................................................................................................21
   Health effects................................................................................................................21
7. Chromium(VI) (hexavalent chromium) (and compounds) ................................................................. 24
   Use of chromium(VI) and compounds ......................................................................................... 24
   Chromium compounds ................................................................................................................. 24
   Occupational exposure .................................................................................................................. 25
   Health effects ............................................................................................................................... 25
   EU and IARC classification ......................................................................................................... 26
   Legislation .................................................................................................................................... 26

8. Cobalt ........................................................................................................................................... 28
   Mining and refinery of cobalt ........................................................................................................ 28
   Use of cobalt .................................................................................................................................. 28
   Cobalt compounds ....................................................................................................................... 30
   Occupational exposure .................................................................................................................. 30
   Health effects ............................................................................................................................... 32
   EU and IARC classification ......................................................................................................... 32
   Legislation .................................................................................................................................... 33

9. Diesel engine exhaust emissions ............................................................................................... 34
   Occupational exposure .................................................................................................................. 34
   Health effects ............................................................................................................................... 34
   EU and IARC classification ......................................................................................................... 35
   Legislation .................................................................................................................................... 35

10. Diethyl sulphate/dimethyl sulphate ............................................................................................ 36
    Use of diethyl sulphate ................................................................................................................... 36
    Use of dimethyl sulphate .............................................................................................................. 36
    Health effects ............................................................................................................................. 36
    EU and IARC classification ........................................................................................................ 37
    Legislation .................................................................................................................................... 37

11. Epichlorohydrin ............................................................................................................................ 38
    Use of epichlorohydrin ................................................................................................................... 38
    Occupational exposure .................................................................................................................. 38
    Health effects ............................................................................................................................... 38
    EU and IARC classification ......................................................................................................... 38
    Legislation .................................................................................................................................... 39

12. Ethylene oxide ............................................................................................................................. 40
    Use of ethylene oxide ................................................................................................................... 40
    Occupational exposure .................................................................................................................. 40
    Health effects ............................................................................................................................... 40
    EU and IARC classification ........................................................................................................ 41
    Legislation .................................................................................................................................... 41
13. Formaldehyde ................................................................. 42
   Use of formaldehyde ....................................................... 42
   Occupational exposure .................................................... 45
   Health effects ............................................................... 45
   EU and IARC classification .............................................. 45
   Legislation ................................................................. 46
14. Lead (and its inorganic compounds) ..................................... 47
   Use of lead ................................................................. 47
   Lead compounds .......................................................... 48
   Occupational exposure .................................................... 49
   Health effects ............................................................... 50
   EU and IARC classification .............................................. 51
   Legislation ................................................................. 51
15. Mineral oils (as mists) ...................................................... 54
   Use of mineral oils ......................................................... 54
   Mineral oils as used engine oils ....................................... 54
   Occupational exposure .................................................... 55
   Health effects ............................................................... 55
   EU and IARC classification .............................................. 55
   Legislation ................................................................. 56
16. Nickel (and compounds) ................................................... 57
   Use of nickel ............................................................... 57
   Nickel compounds ........................................................ 58
   Occupational exposure .................................................... 59
   Health effects ............................................................... 61
   EU and IARC classification .............................................. 61
   Legislation ................................................................. 62
17. o-Toluidine ..................................................................... 64
   Use of o-toluidine ........................................................... 64
   Occupational exposure .................................................... 64
   Health effects ............................................................... 64
   EU and IARC classification .............................................. 64
   Legislation ................................................................. 65
18. Respirable crystalline silica ............................................... 66
   Use of silica ................................................................. 66
   Occupational exposure .................................................... 66
   Health effects ............................................................... 67
   EU and IARC classification .............................................. 67
   Legislation ................................................................. 68
19. Trichloroethylene ........................................................... 69
Use of trichloroethylene..............................................................................................................69
Occupational exposure..................................................................................................................69
Health effects................................................................................................................................69
EU and IARC classification............................................................................................................69
Legislation ......................................................................................................................................70

20. Ultraviolet radiation..................................................................................................................71
Solar UVR (including ocular exposure)..........................................................................................71
  Reflection......................................................................................................................................71
Measurement of UVR.....................................................................................................................72
Occupational exposure to solar UV.............................................................................................73
Artificial UVR (including ocular exposure)....................................................................................73
  Occupational exposure to artificial UVR....................................................................................74
Health effects of solar and artificial UV .......................................................................................76
EU and IARC classification............................................................................................................77
Legislation ......................................................................................................................................78

21. Ionising radiation .....................................................................................................................79
Use of ionising radiation................................................................................................................79
Occupational exposure..................................................................................................................79
Health effects................................................................................................................................80
EU and IARC classification............................................................................................................81
Legislation ......................................................................................................................................81

22. Leather dust ..............................................................................................................................82
Occupational exposure..................................................................................................................82
Health effects................................................................................................................................82
EU and IARC classification............................................................................................................82
Legislation ......................................................................................................................................82

23. Wood dust .................................................................................................................................83
Occupational exposure..................................................................................................................83
Health effects................................................................................................................................84
EU and IARC classification............................................................................................................84
Legislation ......................................................................................................................................84
Overview table ..............................................................................................................................85

Job categories (job modules) and tasks (task modules) where the exposure to a given cancer risk factor is assessed ..................................................................................................................91
Introduction

This document presents a short description of the cancer risk factors included in the first wave of the Workers’ Exposure Survey on cancer risk factors in Europe (WES). The descriptions are based on documentation for classification and occupational exposure limits (OELs) setting for the risk factors, including the documents related to the amendments to Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens, mutagens or reprotoxic substances at work (Sixth individual Directive within the meaning of Article 16(1) Directive 89/391/EEC), and the criteria documents from the International Agency for Research on Cancer (IARC). An overview table is added at the end of the document. An overview of the modules of the survey in which exposures to the cancer risk factor are assessed is also provided.

The selection of risk factors that were included in WES was supported by an international expert group. The following criteria for inclusion in the survey have been considered and were discussed at the first meeting of the international expert group (in September 2019):

- The risk factor/substance/group of substances is already included in OccIDEAS and the tool has been tested for it and is appropriate.
- In case of chemical substances or mixtures:
  - the substance, mixture or process-generated substance meets the criteria for classification as a category 1A or 1B carcinogen set out in Annex I to Regulation (EC) No 1272/2008 of the European Parliament and of the Council (Classification, Labelling and Packaging (CLP) European Regulation);
  - it is classified in Groups 1 or 2A in IARC classification (last update);
  - it is included in the directive or in one of the planned or adopted revisions of the European Directive for the protection of workers against carcinogens or mutagens at work (CMD), now Directive for the protection of workers against carcinogens, mutagens or reprotoxic substances (CMRD); this may lead to inclusion of the risk factor or its exclusion from the survey.

Additional criteria for the selection of risk factors may be:

- They cause occupational exposures across sectors or occupations (for example, welding is applied in many sectors and exposures to constituents of welding fumes may affect many workers).
- Number of workers potentially exposed, where such information is available (for example, from the European Commission’s background studies for OEL setting).

The following criteria for inclusion were applied in the Australian survey (criteria set in 2012):¹

- classified as Group 1 or 2A by the IARC classification;²
- used in Australia; and
- occupational exposure.

¹ Australian Work Exposures Study (AWES).
² The latest IARC update considered was from 2014.
Risk factors included in the Workers’ Exposure Survey – background information by cancer risk factor

1. Acrylamide

Acrylamide is an organic compound, a white odourless solid, soluble in water and several organic solvents. Acrylamide is available as a solid (either crystals or briquettes) and in aqueous solution.

Use of acrylamide

Acrylamide is a vinyl monomer that improves the aqueous solubility, adhesion and cross-linking of polymers. Water-soluble polyacrylamides are the largest application of acrylamide.

Acrylamide monomer is also used directly as a component of photopolymerization systems, in adhesives and grouts, and in cross-linking agents in vinyl polymers. Acrylamide is a chemical used in sectors such as the paper and pulp, construction, foundry, oil drilling, textiles, cosmetics, food processing, plastics, mining and agricultural industries. It is used in treating drinking water and wastewater. In addition, acrylamide and polyacrylamides are used in the production of dyes and organic chemicals, contact lenses, cosmetics and toiletries, permanent-press fabrics, paper and textile production, pulp and paper production, ore processing and sugar refining, and as a chemical grouting agent and soil stabiliser for the construction of tunnels, sewers, wells, and reservoirs. It can be found in small amounts in consumer products including caulk, food packaging and some adhesives.

Acrylamide can also form naturally from chemical reactions in certain types of starchy foods, after cooking at high temperatures. Some foods with higher levels of acrylamide include French fries, potato chips, foods made from grains (such as breakfast cereals, cookies and toast), and coffee. So it exists in most baked goods, fried potatoes, coffee, and other hot foods and drinks. It also occurs naturally in many vegetables and fruits without heating. It is also present in cigarette smoke. Acrylamide monomer may also be sold for on-site preparation of polyacrylamide gels.

Ninety-nine per cent of acrylamide industrially produced in the EU, meaning not occurring as a by-product from combustion, for instance, is used in the production of polyacrylamide. The main uses of polyacrylamide are in wastewater treatment, paper and pulp processing, and mineral processing. About 0.1% of the acrylamide produced in the EU is used to produce polyacrylamide electrophoresis gels, which are used as a research tool for separating nucleic acids in research establishments, universities and hospitals.

An Institute of Occupational Medicine (IOM) report produced for DG EMPL found seven producers of polyacrylamide within the EU (two of which also produced acrylamide) in 2010, as well as a number of smaller producers throughout the EU. Three companies were reported as producing acrylamide within the EU (in Germany, the Netherlands, and the United Kingdom (UK)). There were also thought to be firms in Spain, Italy and Finland that either supply (from imports) or produce acrylamide. The total plant capacity within the EU is estimated at between 80,000 and 150,000 tonnes per year.

Occupational exposure

Occupations in which there is potential exposure to acrylamide include: chemical production; construction and maintenance involving pipe grouting and sealing; soil, tunnel and dam stabilisation; water and wastewater treatment; and preparation of polyacrylamide gels in the laboratory. The potential for exposure to acrylamide has been decreased by the use of commercially prepared polyacrylamide gel plates. Exposure to acrylamide polymer may lead to exposure to acrylamide, since the polymer may contain small amounts of monomer. Exposures may occur in monomer and polymer production from

---

inhalation of dry powder or crystalline monomer, dermal contact with the monomer or dermal contact with solutions of acrylamide.

In the staff working document accompanying the first amendment of the CMD, 54,000 EU workers were estimated to be exposed to acrylamide. It was also noted that the global market for polyacrylamide had been growing and was expected to continue expanding.\(^5,6\)

**Health effects**

Acrylamide may cause pancreatic cancer and is also a skin irritant, and may be a tumour initiator in the skin, potentially increasing risk for skin cancer. Symptoms of acrylamide exposure include dermatitis in the exposed area and peripheral neuropathy.

**EU and IARC classification**

Acrylamide is classified as a Group 2A carcinogen (‘Probably carcinogenic to humans’) by the IARC.\(^7\)

According to the harmonised classification and labelling approved by the EU, this substance is toxic if swallowed, may cause genetic defects, may cause cancer, causes damage to organs through prolonged or repeated exposure, is harmful in contact with skin, causes serious eye irritation, is harmful if inhaled, is suspected of damaging fertility, causes skin irritation and may cause an allergic skin reaction.\(^8\) Acrylamide meets the criteria for classification as carcinogenic (category 1B) in accordance with Regulation (EC) No 1272/2008 and therefore is a carcinogen within the meaning of Directive 2004/37/EC.\(^9\) Acrylamide has a harmonised classification as a skin irritant (category 2) and skin sensitiser (category 1).

**Legislation**

Acrylamide is identified under Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as a substance of very high concern (SVHC) and included in the Candidate List for authorisation. Some uses of this substance are restricted under Annex XVII of REACH. It shall not be placed on the market or used as a substance or constituent of mixtures in a concentration equal to or greater than 0.1% by weight for grouting applications.

Binding occupational limit values for acrylamide were last set in 2017 with the first amendment to the CMD,\(^10\) now CMRD, with the notice that a substantial contribution to the total body burden via dermal exposure is possible.\(^11\) Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with this Directive by 17 January 2020. The Scientific Committee on Occupational Exposure Limits (SCOEL) identified for acrylamide the possibility of significant uptake through the skin and recommended to assign to it a notation indicating the possibility of significant dermal uptake.\(^12\)

---


\(^8\) ECHA chemical infocard - acrylamide: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.001.067


\(^11\) See: https://eur-lex.europa.eu/resource.html?uri=cellar:ef3196db-18f4-11e6-ba9a-01aa75ed71a1.0009.02/DOC_1&format=PDF

\(^12\) Recommendation from the Scientific Committee on Occupational Exposure Limits for Acrylamide, SCOEL/SUM/139, September 2011/Annex December 2012: http://ec.europa.eu/social/BlobServlet?docId=7421&langId=en
2. Arsenic (and compounds)

Arsenic occurs naturally in the environment as an element of the Earth’s crust. Arsenic is combined with other elements such as oxygen, chlorine and sulphur to form inorganic arsenic compounds. Exposure to higher-than-average levels of arsenic occurs mainly in workplaces, near or in hazardous waste sites, and areas with high levels naturally occurring in soil, rocks and water.

**Use of arsenic**

Arsenic is naturally present as impurity in ores, fossil fuels, soil, and plant material and may be released to the air by thermal processing/combustion of these materials. Furthermore, arsenic compounds would be present in dust formed by the processes.

Chromated copper arsenate (CCA)-treated timber, copper smelting (of lower-grade ores), and metal extraction and handling of mining waste have become the most prevalent sources of occupational exposure to arsenic. Historically, diarsenic pentaoxide was used in CCA wood preservatives. Occupational exposure to arsenic from CCA wood preservatives mainly occurs today from dismantling of wooden structures and recycling of wood, as treatment of wood and imports of CCA-treated timber in the EU is banned since 2013. Occupational exposure to arsenic may also be significant in other industries, such as arsenic production, electronics (gallium arsenide semiconductors), glass manufacturing and in the pharmaceutical industry.\(^\text{13}\)

It is extremely rare for workers to be exposed to arsenic alone; the exposure is usually to arsenic in combination with other elements. Inorganic arsenic compounds are intentionally used in the glass sector, electronics sector and the primary zinc sector. Production of glass is together with the electrowinning of zinc the major application of arsenic compounds.

**Arsenic compounds**

Two arsenic compounds are used in significant quantities: arsenic acid and diarsenic trioxide. Both substances are used as fining agents in the production of glass.

Arsenic compounds are also used for various applications in the manufacture of electronic components and printed circuit boards. Exposure by inhalation may take place by the use of the substances for the manufacture of the components (manufacture of copper foils, gold plating of circuit boards), whereas exposure by the later use of the components and printed circuit boards for production of electronics is considered insignificant.

**Diarsenic trioxide** and arsenic acid are manufactured as a by-product by two EU companies by recovery from waste products from the production of non-ferrous metals. Available information indicated that occupational exposure to arsenic would potentially take place when sulphuric acid is produced in the non-ferrous metal sector, and in particular in the copper sector, and when it is produced from pyrite. Exposure to arsenic in the copper sector could basically take place by three activities: primary copper production; secondary copper production where arsenic may originate from recycled copper-arsenic alloys or arsenic impurities in the recycled materials; and production and casting of copper-arsenic alloys. Arsenic oxides may be formed by the melting of the alloys. In the process, the arsenics can be released, for example, in fumes, dusts and skimming. Gold, silver and platinum group metals and other metals such as selenium, cobalt and germanium are produced either from ore concentrates, from waste products from other non-ferrous metal production, or from scrap, for example, from electronic products. Arsenic may be present in all the raw materials, for example, in the form of nickel arsenide, but in particular large quantities are processed with waste products from other non-ferrous metal production. Some of these activities are undertaken at sites manufacturing primary copper.

Traditionally, diarsenic trioxide has been used by taxidermists for the preservation of animals. Diarsenic trioxide was the most used biocidal product for ‘dry’ preservation. The exposure for museum workers today, for example, is considered low.

---

Occupational exposure

Arsenic exposure in the workplace occurs through inhalation, ingestion, or dermal or eye contact.

According to the staff working document, the estimated total for the (then) EU-28 of exposed workers was 25,300 to 116,200, but this figure may be significantly underestimated.

Occupational exposure to inorganic arsenic compounds may take place in a number of processes, including production and processes involving alloys with arsenic metal and thermal processes where arsenic is present as unintentional impurity in raw materials.

In addition to the exposures mentioned above, exposure to arsenic by welding is often mentioned in general introductions to exposure to hazardous substances in welding. Data from the German MEGA database14 demonstrate exposure to arsenic in different welding and thermal cutting processes. Data from the German MEGA database also indicates that exposure to arsenic may take place by various processes in the metal industry such as soldering, casting/melting and similar process, dry sanding and various machining processes.

Workers in coal and oil-shale powered power plants may be exposed to arsenic in fly ash during cleaning. Fly ash contains arsenic and a number of other heavy metals that the workers are exposed to, for example, during cleaning and maintenance.

Health effects

Exposure to high levels of arsenic can cause death. Chronic exposure to arsenic at low levels for extended periods of time can cause a discoloration of the skin and lead to distinct skin diseases, such as: arsenical keratinosis, which is characterised by excessive formation of scaly skin on the palms and soles; darkened patches of skin; wart formation; skin lesions; acne; and increased risk of skin cancers. Chronic arsenic poisoning can also cause: sudden constriction in arteries or veins, known as 'black foot disease', reducing blood flow; decreased nerve function; and lung, liver, kidney, bladder and other cancers. Acute exposures can cause lung distress and death.15

Inorganic arsenic compounds produce lung tumours in humans, following inhalation, oral or parenteral exposures. Exposure to high levels of inorganic arsenic compounds in drinking water has been associated with skin and urinary tract or bladder cancers or both in humans. Tumours at other sites including the adrenal glands, bladder and liver have also been reported in some animal studies. Relevant non-carcinogenic end-points of occupational exposure are neurotoxicity and cardiovascular effects. Immunotoxicity and reproductive and developmental effects have been observed in animal studies with inhalation exposure.

EU and IARC classification

Arsenic acid and its salts are classified as carcinogen category 1A under the Classification, Labelling and Packaging Regulation (EC) 1272/200816 (CLP Regulation), and the broader group arsenic and inorganic arsenic compounds are considered to be human carcinogens (Group 1) by the IARC.

According to the harmonised classification and labelling approved by the EU, diarsenic trioxide is fatal if swallowed, causes severe skin burns and eye damage, and may cause cancer (carcinogen category 1A).17 The classification provided by companies to the European Chemicals Agency (ECHA) in REACH registrations identifies that diarsenic trioxide may damage fertility or the unborn child, causes damage to organs through prolonged or repeated exposure, is suspected of causing genetic defects, may cause an allergic skin reaction, and may cause allergy or asthma symptoms or breathing difficulties if inhaled.

---

14 See: https://www.dguv.de/ifa/gestis/expositionsdatenbank-mega/index-2.jsp
15 See: https://www.osha.gov/arsenic/hazards
17 ECHA substance infocard - diarsenic trioxide: https://echa.europa.eu/substance-information/-/substanceinfo/100.014.075
According to the harmonised classification and labelling approved by the EU, diarsenic pentaoxide is toxic if swallowed, is toxic if inhaled, and may cause cancer (carcinogen 1A).\textsuperscript{18}

**Legislation**

Arsenic acid and its salts, as well as some inorganic arsenic compounds, are covered by the CMRD.\textsuperscript{19} Arsenic acid and its salts are subject to authorisation (Annex XIV). Diarsenic trioxide and pentaoxide are subject to authorisation according to REACH. In 2003, in EU Directive 2003/02/EC,\textsuperscript{20} the Commission restricted the use of arsenic-containing wood preservatives. According to the directive, arsenic compounds may not be used in the preservation of wood and wood treated with arsenic compounds may not be put on the market unless the structural integrity of the wood is required for safety reasons and dermal contact with the wood by the general public is unlikely. This directive has meant that the use of CCA in wood preservatives has effectively ceased in the EU. The use of CCA solutions in the preservation of timber and import of CCA-treated timber is regulated by the Biocidal Product Regulation and is no longer permitted; its use is further restricted under Annex XVII of the REACH Regulation.

Binding OELs for arsenic acid and its salts, as well as inorganic arsenic compounds, were last set in 2019 with the third amendment to the CMD (now CMRD).\textsuperscript{21} Following the publication of the third revision of the directive, Member States had to transpose it into their national legislation by 11 July 2021 at the latest. For the copper smelting sector, the limit value should apply from 11 July 2023.

\textsuperscript{18} ECHA substance infocard - diarsenic pentaoxide: https://echa.europa.eu/substance-information/-/substanceinfo/100.013.743

\textsuperscript{19} The substances covered by the impact assessment for the third amendment of the CMD (now CMRD) include diarsenic pentaoxide; diarsenic trioxide; arsenic acid, sodium salt; arsenic acid; disodium hydrogenarsenate; calcium arsenate; arsenic trichloride; potassium dihydrogenarsenate; diammonium hydrogenarsenate; sodium dioxaarsenate; iron arsenate; iron bis(arsenate); arsenic acid, magnesium salt; arsenic acid, copper salt; arsenic acid, calcium salt; ammonium dihydrogenarsenate; trisodium arsenate; zinc arsenate; sodium metarsenate; triammonium arsenate; 3-methyl-4-(pyrrolidin-1-yl)benzenediazoniumhexafluoroarsenate; arsenic acid, copper(2+) salt; vanadium(4+) diarsenate (1:1); sodium hexafluoroarsenate(V); calcium hydrogen arsenate; and sodium arsenate dibasic heptahydrate.


3. Asbestos

Asbestos is the generic term for a group of naturally occurring mineral silicate fibres. These include the serpentine mineral chrysotile (also known as ‘white asbestos’) and the five amphibole minerals — actinolite, amosite (also known as ‘brown asbestos’), anthophyllite, crocidolite (also known as ‘blue asbestos’), and tremolite. The structure of silicate minerals may be fibrous or non-fibrous. The terms ‘asbestos’ or ‘asbestiform minerals’ refer only to those silicate minerals that are composed of extremely flexible fibres with a relatively small diameter and a large length. Historically, there has been a lack of consistency in asbestos nomenclature. This frequently contributed to uncertainty in the specific identification of asbestos minerals reported in the literature.

Use of asbestos

Asbestos fibres tend to possess: good strength properties (e.g. high tensile strength, wear and friction characteristics); flexibility (e.g. the ability to be woven); excellent thermal properties (e.g. heat stability; thermal, electrical and acoustic insulation); adsorption capacity; and resistance to chemical, thermal and biological degradation. These chemical and physical properties make it desirable for a wide range of industrial applications. The range of applications in which asbestos has been used includes roofing, thermal and electrical insulation, cement pipe and sheets, flooring, gaskets, friction materials (e.g. brake pads and shoes), coating and compounds, plastics, textiles, paper, mastics, thread, fibre jointing and millboard.

Asbestos was used as a loose fibrous mixture, bonded with other materials (e.g. Portland cement, plastics and resins), or woven as a textile. Asbestos products can be subdivided as follows:

- Weakly bound forms (such as sprayed asbestos, mats, ropes, cardboard) – low density. These products possess a high concentration of asbestos and low binder content.
- Strongly bound forms (particularly asbestos cement) – high density. Binder content is high, and the concentration of asbestos generally amounts to less than 20%.

Certain fibre characteristics, such as length and strength, determined the most appropriate application. For example, longer fibres tended to be used in the production of textiles, electrical insulation and filters; medium-length fibres were used in the production of asbestos cement pipes and sheets, friction materials (e.g. clutch facings, brake linings), gaskets and pipe coverings; and short fibres were used to reinforce plastics, floor tiles, coatings and compounds, and roofing felts.

With more than 90% (globally), chrysotile made up the largest portion of asbestos used in production, mainly serving as an additive or admixture but also manufactured into mats and ropes. Crocidolite has a share of approximately 5% and was predominantly used as sprayed asbestos and in high-temperature lagging. In contrast, amosite amounts to less than 2%. In all European countries, an estimated 70-80% of raw asbestos by weight was used for the manufacturing of cement products. The rest was used for construction products, floor coverings, brake linings, asbestos textiles, insulating board, spray insulation, filter materials and so on.

Since the 1970s, there has been a general decline in world production and consumption of asbestos. Peak world production was estimated to be 5.09 million metric tons in 1975, with approximately 25 countries producing asbestos and 85 countries manufacturing asbestos products. Peak use of asbestos was higher and occurred earlier in the countries of northern and western Europe, Oceania, and the Americas (excluding South America). Very high asbestos use was recorded in Australia (5.1 kg per capita/year in the 1970s), Canada (4.4 kg per capita/year in the 1970s), and several countries of northern and western Europe (Denmark: 4.8 kg per capita/year in the 1960s; Germany: 4.4 kg per capita/year in the 1970s; and Luxembourg: 5.5 kg per capita/year in the 1960s).

---

Occupational exposure

Inhalation and ingestion are the primary routes of exposure to asbestos. Dermal contact is not considered a primary source, although it may lead to secondary exposure to fibres, via ingestion or inhalation. The degree of penetration in the lungs is determined by the fibre diameter, with thin fibres having the greatest potential for deep lung deposition.

Asbestos has been in widespread commercial use for over 100 years. In Europe, estimates of the number of workers exposed to asbestos have been developed by CAREX (CARcinogen EXposure). Based on occupational exposure to known and suspected carcinogens collected during the period 1990-1993, the CAREX database estimated that a total of 1.2 million workers were exposed to asbestos in 41 industries in the 15 Member States of the EU at the time. Families of asbestos workers may have been exposed via contact with fibres carried home on hair or on clothing. In a recent study commissioned by the European Commission, it was estimated that currently 4.1 to 7.3 million workers were exposed to asbestos, with the major share (3.5 to 5.5 million) being workers in a situation of sporadic and low-intensity exposure.23

Asbestos-related risks persist and are expected to be a health-risk factor in the context of the European Green Deal ‘renovation wave’, aimed at helping make buildings fit for a climate-neutral Europe.24 More than 220 million building units, representing 85% of the EU’s building stock, were built before 2001 and, therefore, before the use of asbestos was banned in all EU Member States. Those buildings will be renovated (either for maintenance or aesthetic purposes or for energy efficiency reasons) or demolished and replaced by new construction. Major occupational exposure sources nowadays include the removal of asbestos-containing materials when carrying out maintenance (such as on clutches and brakes on cars and trucks or the insulation of stoves); transport and disposal of wastes containing asbestos; and demolition, sanitation and maintenance of buildings constructed with asbestos-containing products, such as insulation, fireproofing, ceiling and floor tiles, roof shingles, drywall and cement.

Health effects

Asbestos is still one of the main causes of work-related cancers, despite its EU-wide ban, due to the long average latency of the cancers caused by asbestos. Asbestos causes mesothelioma, cancers of the lung and larynx, and ovarian and gastrointestinal carcinoma. Positive associations have also been observed between exposure to all forms of asbestos and cancers of the pharynx, stomach and colorectum. Asbestos can also cause other health effects, such as pulmonary fibrosis (asbestosis) and pleural plaques.

EU and IARC classification

According to the IARC, there is sufficient evidence in humans for the carcinogenicity of all forms of asbestos. All forms of asbestos (chrysotile, crocidolite, amosite, tremolite, actinolite and anthophyllite) have been classified by the IARC as carcinogenic to humans (Group 1). Actinolite,25 amosite,26 anthophyllite,27 chrysotile,28 crocidolite29 and tremolite30 also have a harmonised classification as carcinogen 1A according to the CLP Regulation.

References:


26 ECHA substance infocard - amosite: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.121.453


Legislation

Asbestos products were banned in all the countries of the EU, including Member States of eastern Europe, effective 1 January 2005, with Commission Directive 1999/77/EC, with a few exceptions. Most uses are restricted under Annex XVII of REACH.

Exposure to asbestos in occupational settings is regulated in the EU. A binding OEL has been last been set in Directive 2023/2668/EU amending the directive from 2009, and a number of additional provisions have been introduced in this directive. Member States have to comply with the 2023 amendments (Directive 2023/2668/EU) by 21 December 2025. Transitional measures (graded lowering of the limit values) apply to a further lowering of the limit value and the introduction of electron microscopy method for measuring asbestos fibres. A guidance document for the information and training of workers involved with asbestos removal or maintenance work is also available. In addition, the Commission will provide Member States with guidelines to facilitate the implementation of the revised directive, covering aspects such as modern fibre-counting methods, training programmes and personal protective equipment (PPE), as well as risks to firefighters and emergency services, building on best practices available in the Member States and on the consultation of relevant stakeholders.

The European Parliament had already adopted a resolution on asbestos-related occupational health threats in March 2013, in which it had called on the EU to develop a model for asbestos screening and registration in the Member States. On 27 September 2021, the Parliament’s Committee on Employment and Social Affairs (EMPL) adopted an own-initiative legislative report with recommendations to the Commission on protecting workers from asbestos. It recommends the Commission present a ‘European strategy for the removal of all asbestos’ (ESRRA) in the EU, with an integrated approach connecting several policy areas to safely remove all asbestos from the built environment, while strengthening the protection of workers and the support for victims and their families, and taking the owners of the buildings into consideration.

In a communication to follow up on the European Parliament’s resolution of 20 October 2021 on protecting workers from asbestos, the European Commission has outlined an approach on working towards an asbestos-free future, tackling asbestos in a comprehensive way. This includes identification and safe removal and waste treatment.

---

33 The Directive, targets the risk arising from exposure to asbestos at work through defining a series of measures including prohibiting certain activities using asbestos; prohibiting other uses of asbestos; introducing measures to reduce exposure to asbestos to a minimum (and in any case below the limit value laid down); establishing maximum limits for exposure to asbestos; requiring the measurement of asbestos exposures; in the case of certain activities such as demolition, asbestos removal work, repairing and maintenance, taking the appropriate measures to ensure protection of the workers while they are engaged in such activities; monitoring the health of those working with asbestos.
38 Communication from the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions on working towards an asbestos-free future: a European approach to addressing the health risks of asbestos, COM(2022) 488 final, of 28 September 2022: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A488%3AFIN

European Agency for Safety and Health at Work – EU-OSHA

14
4. Benzene

Benzene occurs both naturally and as a result of human activity, notably as a result of combustion. It is a high-volume chemical now used mostly as a chemical intermediate. Human exposure to benzene is widespread, through the air, in consumer products and in industry.

**Use of benzene**

Benzene is one of the highest volume substances. Benzene is produced in petroleum refinery and chemical plant processes, primarily by catalytic reforming, steam cracking and dealkylation. Benzene is also formed during coking of coal. Benzene and other aromatics are present in the coke oven gas and can also be recovered during production of coal-derived chemicals, primarily from coke oven by-products. It is extracted from these sources and purified for industrial use.

According to REACH information, benzene is manufactured in and/or imported into the European Economic Area in a quantity of 1 million to 10 million tonnes per year. In 2014, the industry reported benzene production and consumption in the EU-15 and in the EU-15 plus Norway and Switzerland of 6.7 and 7.5 million tonnes, respectively. The main part of the produced benzene — about 90% — is derived from crude oil using processes such as catalytic reforming (20%), toluene hydrodealkylation (20%), and pyrolysis of naphtha and gas oil (50%). The main source in former times, coal carbonisation, now provides less than 10% of the benzene production.

Historically, benzene was used as a degreaser of metals, a solvent for organic materials, a starting and intermediate material in the chemical and drug industries (e.g. to manufacture rubbers, lubricants, dyes, detergents and pesticides), and an additive to unleaded gasoline.

Benzene up to 1% v/v may be contained in petrol as an anti-knocking agent. Before 2000, the concentration of benzene in petrol was usually 2% or higher.

Within the petroleum/petrochemical industry, sampling and analysis of benzene-containing streams is an integrated part of the business. Small quantities of benzene are used as a laboratory reagent and solvent. This use is declining; however, benzene does occur in small quantities in various solvents on a hydrocarbon basis.

Benzene use has diminished since its carcinogenic properties became widely publicised. The main uses of benzene are as constituent of petrol and as a raw material in the chemical industry for the production of ethylbenzene, styrene, cumene, cyclohexane, nitrobenzenes, alkylbenzenes, maleic anhydride and chlorobenzenes. The use of benzene for the production of ethylbenzene, cumene, cyclohexane and nitrobenzene accounts for 90% of annual benzene consumption. It is an intermediate in the production of anthraquinoine, hydroquinone, benzene hexachloride, benzene sulphon acid, and other products used in drugs, dyes, insecticides and plastics.

**Occupational exposure**

Due to the high volatility of benzene, occupational exposure to benzene mainly occurs via inhalation. Benzene also penetrates skin, but dermal absorption will vary according to the tasks being performed (e.g. dipping machinery parts, immersion of hands, or using petroleum-based products as degreasing agents), the benzene content of the product, the composition of the product containing benzene, contact time and the area of the body on which the chemical resides.

Benzene is a ubiquitous pollutant that is present in several industries and occupations, including the production and refining of oil and gas, the distribution, sale and use of petroleum products, coke production, the manufacture and use of chemical products, automobile repair, shoe production, firefighting and various operations related to engine exhaust. Some activities, such as tank maintenance and cleaning, and loading/unloading of benzene-containing streams, are relevant for numerous sectors. There have also been some reports on exposure to benzene during handling of various types of jet fuel.

Benzene is a natural component of crude oil and natural gas/natural gas liquids and present in certain streams of refining and steam cracking output products (naphtha and pyrolysis gasoline). The benzene content in crude oil differs between the oil fields. Benzene is extracted from benzene-containing streams. Workers who carry out maintenance work during turnaround, tank maintenance and cleaning, natural gas condensate loading, sampling, repair, maintenance and exchange of valves and pumps or loading and unloading of benzene or benzene-containing streams, for example naphtha, petrol in the upstream
or downstream petroleum industry (crude oil or natural gas production, refineries (processing crude oil and natural gas), steam crackers, aromatics extraction units or manufacturers of refined petroleum products) may be exposed.

Coking plants are often located in vicinity to sites of iron and steel production. Coke is used as metallurgical coke in blast furnaces for metal smelting or for heating. To a lesser extent, coke is produced for heating purposes. Benzene is a by-product in the coking of hard coal. Benzene is also recovered from coke oven gas and tar. In coking plants workers can be exposed when carrying out maintenance work on the coke oven battery or in the by-product plant. In foundries, benzene may be formed and emitted during pyrolysis of organic binders in casting and moulding processes and workers may be exposed.

As mentioned above, pure benzene is also used as a raw material for manufacture of basic chemicals. Workers can be exposed during tank maintenance and cleaning, styrene production, or when loading and unloading benzene.

Filling assistants at petrol stations (primarily southern Europe) or in pump calibration and maintenance and those in repairing workshops for cars, ships, aeroplanes and other vehicles may be exposed to benzene from the use of petroleum-based products.

Groups of workers potentially exposed from the use of petroleum-based products containing benzene as a solvent or as impurity, for example, lacquers, paints, glues and inks, include those in the printing industry, shoe manufacture, rubber manufacture and surface treatment, and the manufacture of artificial leather.

Benzene is also a by-product of combustions. Traffic police, filling assistants at petrol stations (primarily in southern Europe), landscape and forestry workers using petrol-engine equipment, and taxi drivers may be exposed to benzene from exhaust of vehicles/equipment as a result of incomplete combustion. Because of the incomplete combustion and pyrolysis of organic and synthetic materials, respectively, firefighters, for instance, are also potentially exposed to benzene during firefighting (municipal and wildfire), overhaul and training.

According to the study underlying the impact assessment for the fourth amendment to the CMD, now CMRD, the estimates based on different information sources (CAREX, CAREX Canada, SUMER, Finnish ASA register) vary between approximately 200,000 and 10 million workers exposed to benzene, with the total exposed workers included in the assessment of this study at 1,012,500.

Health effects

Benzene causes acute myeloid leukaemia in adults. Positive associations have also been observed for non-Hodgkin lymphoma, chronic lymphoid leukaemia, multiple myeloma, chronic myeloid leukaemia, acute myeloid leukaemia in children and cancer of the lung.

EU and IARC classification

According to the harmonised classification and labelling approved by the EU, benzene may be fatal if swallowed and enters airways, may cause genetic defects, may cause cancer, causes damage to organs through prolonged or repeated exposure, is a highly flammable liquid and vapour, causes serious eye irritation and causes skin irritation. Benzene meets the criteria for classification as carcinogenic (category 1A) in accordance with Regulation (EC) No 1272/2008 and is therefore a carcinogen within the meaning of Directive 2004/37/EC. Benzene can also be absorbed through the skin.

Benzene is also classified as a Group 1 carcinogen by the IARC.
Legislation

Benzene concentration in fuels sold in the EU must be less than 1.0% by volume.\textsuperscript{42} Benzene has a binding biological limit value and OEL according to the fourth amendment to the CMD (now CMRD).\textsuperscript{43} A transitional period of four years after entry into force of this directive has been introduced. As a transitional measure, the limit value provided for in Directive (EU) 2019/130 of the European Parliament and the Council should continue to apply until 5 April 2024 and a transitional limit value should apply from 5 April 2024 until 5 April 2026.


5. 1,3-Butadiene

1,3-Butadiene is a chemical made from the processing of petroleum. It is a colourless, flammable gas with a mild gasoline-like odour.

**Use of 1,3-butadiene**

About 75% of the manufactured 1,3-butadiene is used to make synthetic rubber. Synthetic rubber is widely used for tires on cars and trucks. 1,3-Butadiene is also used to make plastics including acrylics. Small amounts are found in gasoline.\(^{44}\)

Most 1,3-butadiene is polymerised at a relatively small number of sites in Europe to form synthetic rubber. It is used in the following products: adhesives and sealants, anti-freeze products, coating products, fillers, putties, plasters, modelling clay, finger paints, non-metal-surface treatment products, inks and toners, leather treatment products, lubricants and greases, polishes and waxes, polymers, and textile treatment products and dyes. It is also used as a chemical intermediate in the production of neoprene for automotive and industrial rubber goods, in the production of methyl methacrylate-butadiene-styrene polymer, which is used as a polyvinylchloride (PVC) reinforcing agent, and in the production of adiponitrile (a nylon precursor).

The production capacity in the EU was estimated to be 2.9 million tonnes. The production or use of this substance was estimated to be concentrated in a few Member States (such as France, Germany, Poland, Spain, Romania and the UK (then)). An estimate of number of exposed workers by country is included in the impact assessment document for the first amendment of the CMD (reference 38, p. 155).\(^{45}\)

There were nine plant sites producing emulsion of styrene-butadiene rubber (SBR) in July 2010 according to an IOM report produced for DG EMPL,\(^{46}\) four producing solutions of SBR, seven producing polybutadiene or butadiene rubber, and six producing nitrile butadiene rubber. Some of the sites produced two or more of these elastomers at the same location. All companies affected by the proposed OEL value of 1 ppm would be SMEs, and the great majority of them (about 90%) would be microenterprises (fewer than 10 employees).

**Occupational exposure**

About 27,600 workers in the EU were estimated to be potentially exposed to 1,3-butadiene.

**Health effects**

1,3-butadiene exposure is associated with an increased risk of lymphohematopoietic cancer, mainly lymphosarcoma.

**EU and IARC classification**

The IARC has classified 1,3-butadiene as carcinogenic to humans (Group 1).\(^{47,48}\)

According to the harmonised classification and labelling approved by the EU, this substance may cause genetic defects, may cause cancer and is an extremely flammable gas. It is classified as a carcinogen 1A — may cause cancer. Additionally, the classification provided by companies to the ECHA

---

\(^{44}\) See: [https://pubchem.ncbi.nlm.nih.gov/compound/1_3-Butadiene](https://pubchem.ncbi.nlm.nih.gov/compound/1_3-Butadiene)


Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

in REACH registrations identifies that it is suspected of damaging fertility or the unborn child, is harmful to aquatic life with long-lasting effects and that it may explode if heated.\(^{49}\)

**Legislation**

Binding OELs for 1,3-butadiene were last set in 2017 with the first amendment to the CMD (now CMRD),\(^{50}\) with the notice that a substantial contribution to the total body burden via dermal exposure is possible. Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with this directive by 17 January 2020.

---

\(^{49}\) ECHA substance infocard - buta-1,3-diene: https://echa.europa.eu/es/brief-profile/-/briefprofile/100.003.138

6. Cadmium (and compounds)

Cadmium is a rare element not found in its pure state in nature. Instead, it occurs mainly as cadmium sulphide (or greenockite) in deposits of zinc.

**Use of cadmium**

Today, most cadmium metal is produced as a by-product of the extraction, smelting and refining of zinc, lead and copper. In addition, cadmium is also produced from the recycling of spent nickel-cadmium (Ni-Cd) batteries (its largest use), and secondary or recycled cadmium accounts for a notable proportion of cadmium supply. The widespread use of cadmium in such alloys is of importance to a number of sectors. It is used as an alloying element in copper, tin and zinc alloys used in the aerospace industry. Silver electric contacts (silver-cadmium oxide) incorporating 10-15% cadmium are useful in many heavy-duty electrical applications such as relays, switches, circuit breakers and thermostats in the aerospace and defence sector.

Common industrial uses for cadmium and its compounds today are in batteries, alloys, coatings (electroplating), solar cells, plastic stabilisers and pigments, or in brazing or soldering products. Cadmium is also used in nuclear reactors where it acts as a neutron absorber. While lithium-ion batteries have made significant gains in popularity for lightweight electronic devices, new market opportunities for industrial applications of Ni-Cd batteries will continue to fuel cadmium use.51

**Cadmium compounds**

- **Cadmium carbonate** is used as a lab reagent, a component for the production of organic/inorganic cadmium compounds and salts and inorganic pigments, an additive for the production of glass, a component for polymer matrices, plastics and related preparations, and in cadmium carbonate-containing polymers for cable protecting and isolating coatings or for tube and sheet articles or moulded articles, and for cadmium carbonate-containing catalysts.

- **Cadmium oxide** is one of the main precursors to other cadmium compounds and this includes uses in Ni-Cd batteries, photodiodes and photovoltaic cells, catalysts, electroplating, ceramic glazes, pigments, and for veterinary use (nematocides, etc.).

- **Cadmium sulphide** is used mainly for the manufacture of photovoltaic panels and as an intermediate in the manufacture of other cadmium compounds, including pigments. It is also used in small quantities as intermediate in glass colouration. Other uses include as a component for production of inorganic or organic cadmium compounds, as laboratory reagent, in cadmium production by pyrometallurgy, as a component for the production of inorganic pigments, as an additive for production of frits or glass, in the manufacturing of electronic components, in the use of cadmium sulphide-containing catalysts and as a component for the production of photovoltaic modules.

- **Cadmium sulphate** is an important inorganic cadmium compound that is widely used in the semiconductor industry with many excellent physical and chemical properties. Cadmium sulphate monohydrate, which is the form usually marketed, is produced by evaporating a cadmium sulphate solution above 41.5°C.

As well as in photovoltaic applications, **cadmium chloride** is also used as a component for production of organic and inorganic cadmium compounds, in electro-galvanising and electroplating, and as a chemical reagent.

The use of **cadmium fluoride** is probably limited to minor laboratory reagent uses.

**Cadmium nitrate** is a component for the production of inorganic and organic cadmium compounds and inorganic pigments, as a laboratory reagent, as an additive for the production of glass and ceramics, and used in cadmium nitrate-containing catalysts as well as cadmium nitrate-containing photographic emulsions, and in batteries and fuel cells.

51 See: https://www.osha.gov/cadmium
Cadmium hydroxide is used as a component for production of organic and inorganic cadmium compounds in electro-galvanising, in electroplating, as a laboratory reagent, for cadmium production by pyrometallurgy, in the production of inorganic pigments, and in batteries and fuel cells.

**Occupational exposure**

The major routes of occupational exposure are inhalation of dust and fumes and incidental ingestion of dust from contaminated hands, cigarettes or food.

Occupations in which the highest potential exposures occur include cadmium production and refining, Ni-Cd battery manufacture, cadmium pigment manufacture and formulation, cadmium alloy production, mechanical plating, zinc and copper smelting, mining of non-ferrous metal ores, brazing with a silver-cadmium-silver alloy solder and PVC compounding.\(^{52}\) Workers may be exposed during smelting and refining of metals, and manufacturing of batteries, plastics, coatings and solar panels. The expanding Ni-Cd battery recycling industry is a concern for cadmium exposure. Electroplating, metal machining, welding and painting are operations associated with cadmium exposure. Workers involved in landfill operations, the recycling of electronic parts or the recycling of plastics may be exposed to cadmium. Compost workers and waste collectors are also potentially exposed to dust that may contain cadmium. The incineration of municipal waste is another source of cadmium exposure. Recycling of scrap metal may also involve some exposure.\(^{53}\) An overview of the different uses is provided in the staff working document (see for example, pp. 105-106) and in the underlying study.\(^{54}\)

There were estimated to be between 100 and 150 mainly large companies located in the Czech Republic, Germany, France, Italy, the Netherlands and Poland with workforce exposed to significant levels of cadmium in the EU.

About 10,000 workers were estimated to be exposed to cadmium and its inorganic compounds, according to the impact assessment for the third amendment to the CMD (now CMRD),\(^{55}\) but the estimation has a high degree of uncertainty, as considerably higher estimates exist from national sources (see pp. 108-109 of the report). The substances considered were cadmium, cadmium oxide, cadmium sulphide, cadmium fluoride, cadmium chloride, cadmium sulphate, cadmium nitrate, cadmium hydroxide, cadmium carbonate and cadmium(2+) ion bis(nitrile acid). Worker exposure to cadmium can occur in all industry sectors but mostly in manufacturing and construction.

**Health effects**

Cadmium and its compounds are highly toxic and exposure to this metal is known to cause cancer and targets the body’s cardiovascular, renal, gastrointestinal, neurological, reproductive and respiratory systems. Most evidence is available for elevated risk for lung cancer after occupational exposure; however, associations between cadmium exposure and tumours at other locations, including kidney, breast and prostate, may be relevant as well. Cadmium exposure has also recently been associated with pancreatic cancer.\(^{56,57}\) There are contradictory data on dermal sensitisation and no data on sensitisation of the respiratory tract from cadmium exposure. Osteoporosis can also be enhanced by cadmium.

---


**EU and IARC classification**

Cadmium is an established human carcinogen. Cadmium and inorganic cadmium compounds are also classified as reproductive toxicants. According to the classification provided by companies to ECHA in REACH registrations, cadmium is fatal if inhaled, may cause cancer, causes damage to organs through prolonged or repeated exposure, is suspected of causing genetic defects, is suspected of damaging fertility or the unborn child, and catches fire spontaneously if exposed to air. Cadmium and its compounds are covered by several Harmonised Classifications and Labelling (CLH) entries approved by the EU. Cadmium is classified as a carcinogen 1B according to the CLP. 58

According to the harmonised classification and labelling approved by the EU, cadmium carbonate, cadmium nitrate and cadmium hydroxide may cause genetic defects, may cause cancer (carcinogen 1B), cause damage to organs through prolonged or repeated exposure, are harmful if swallowed, are harmful in contact with skin and are harmful if inhaled. 59,60,61

According to the harmonised classification and labelling approved by the EU, cadmium oxide is fatal if inhaled, may cause cancer (carcinogen 1B), causes damage to organs through prolonged or repeated exposure, is suspected of causing genetic defects, and is suspected of damaging fertility and the unborn child. 62

According to the harmonised classification and labelling approved by the EU, cadmium sulphide may cause cancer (carcinogen 1B), causes damage to organs through prolonged or repeated exposure, is harmful if swallowed, is suspected of causing genetic defects, and is suspected of damaging fertility and the unborn child. 63

According to the harmonised classification and labelling approved by the EU, cadmium oxide is fatal if inhaled, is toxic if swallowed, may cause genetic defects, may cause cancer, may damage fertility and may damage the unborn child, and causes damage to organs through prolonged or repeated exposure. 64

According to the harmonised classification and labelling approved by the EU, cadmium chloride and cadmium fluoride are fatal if inhaled, toxic if swallowed, may cause genetic defects, may cause cancer (carcinogen 1B), may damage fertility and may damage the unborn child, and cause damage to organs through prolonged or repeated exposure. 65,66

Cadmium and cadmium compounds are classified as carcinogenic to humans (Group 1) by the IARC.

**Legislation**

Restrictions of the presence of carcinogens, mutagens and reprotoxic substances in mixtures and in articles and their use in industrial processes, established under REACH, apply for cadmium and its inorganic compounds. The placing on the market and use of cadmium and its inorganic compounds in various mixtures and articles has been restricted since 1991, with several amendments. Cadmium and five other cadmium compounds have been identified as SVHCs for possible inclusion in Annex XIV to REACH, the Authorisation list.

---

59 ECHA substance infocard - cadmium carbonate: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.007.427
60 ECHA substance infocard - cadmium nitrate: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.030.633
66 ECHA substance infocard - cadmium fluoride: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.029.293
The EU’s RoHS Directive\textsuperscript{67} restricts cadmium in all electrical and electronic products with very limited exceptions specified in the directive. The limit is 0.01%.

Binding OELs for cadmium and its compounds were last set in 2019 with the third amendment to the CMD (now CMRD).\textsuperscript{68} Following the publication of the third revision of the directive, Member States had to transpose it into their national legislation by 11 July 2021 at the latest.

\textsuperscript{67} Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) Directive. The RoHS Directive currently restricts the use of ten substances: lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), bis(2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP) and diisobutyl phthalate (DIBP).

7. Chromium(VI) (hexavalent chromium) (and compounds)

Chromium occurs naturally in the Earth’s crust, predominately in the trivalent chromium (chromium(III)), form, and it is ubiquitous in air, water, soil and biological materials. Hexavalent chromium (chromium(VI), Cr(VI), chromium 6) is chromium in any chemical compound that contains the element in the +6 oxidation state (thus hexavalent). The hexavalent form rarely occurs naturally.

**Use of chromium(VI) and compounds**

Chromium(VI) and its compounds are used or found in many processes and products, such as: the production and use of stainless steel and other chromium alloys (and during the welding and cutting of these); catalysts in the chemical manufacturing industry; the production of dyestuffs; and leather tanning agents. Industrial uses of chromium(VI) compounds include: chromate pigments in dyes, paints, inks, and plastics and pigments for paint and pottery; chromates added as anticorrosive agents to paints, primers and other surface coatings; and electroplating/anodising and chromic acid electroplated onto metal parts to provide a decorative or protective coating. The main use of chromium(VI) is found in wood preservatives, metal coatings, chromium production and catalyst manufacture.\(^69\)

Chromium(VI) can be formed when performing ‘hot work’ such as welding on chromium-containing metals, stainless steel, or melting chromium metal. In these situations, the chromium is not originally hexavalent, but the high temperatures involved in the process result in oxidation that results in the oxidation of trivalent chromium to produce fumes containing hexavalent chromium. Chromium(VI) can also be found in drinking water and public water systems. Chromium(VI) can also be formed through the combustion of coal and oil, in cement works and waste incineration.

Chromium(VI) compounds are no longer manufactured in Europe, and they are imported less than in the past.

**Chromium compounds**

The five most widely used compounds that contain chromium in the hexavalent oxidation state are sodium chromate, sodium dichromate, chromium trioxide, potassium dichromate and ammonium dichromate.

In 2005, the main uses were: for sodium dichromate, chromium trioxide and potassium dichromate, the production of wood preservation products and metal finishing; for chromium trioxide, potassium dichromate and ammonium dichromate, catalyst and pigment manufacture; and for sodium dichromate and ammonium dichromate, use as a mordant in dyeing. In addition: sodium dichromate was used in production of vitamin K and in the manufacture of Montans wax, a hard wax made from solvent extraction of lignite or brown coal; potassium dichromate in dye and chromium metal manufacture as well as a colouring agent in ceramics production; chromium dioxide in chromium trioxide production; and ammonium dichromate in magnetic tape and pigment manufacture. Since then the manufacture of chromium compounds has ceased in the EU.\(^70\)

Chromium(VI)-containing wood preservatives include CCA, copper chrome (CC), cooper chrome boron (CCB) and copper chrome phosphate (CCP). The restrictions on the use of CCA may have resulted in increased use of CC, CCB and CCP in some Member States.

For the manufacture of pigments and chrome tanning salts, and the formulation of metal treatment compounds, as far as possible the pigment and chrome tanning salt end-products are reduced to chromium(III) compounds. Most chromium pigments and tanning salts used by end users now contain little to no chromium(VI); however, exposure to chromium(VI) still occurs during the manufacture of these products.

---


Metal treatment involving chromium(VI) includes the following:

- electroplating – deposition of a metallic coating on a base material;
- conversion coatings – chemical treatment of a metallic surface to place a complex chromium barrier layer that protects against corrosion; and
- brightening – the use of chromium salt solutions to remove scale or oxide films from metal substrates.

Both trivalent and hexavalent chromium are used in these processes. When chromium(VI) compounds are used, inhalation exposure to chromium(VI) can occur in all three types of processes.

**Occupational exposure**

Chromium(VI) can enter the body by breathing in dust, fumes or mist, skin contact with solutions or solids, and swallowing it, through handling food with chromium dust on the hands.

In 2006, about 917,000 workers in the EU were estimated to be exposed. An estimate of number of exposed workers by country is included in the impact assessment document for the first amendment of the CMD (p. 154).\textsuperscript{71}

Workers in many occupations are exposed to chromium(VI). Problematic exposure is known to occur among workers who handle chromate-containing products and those who grind and/or weld stainless steel. High-pressure treatment was used to apply preservatives to wood. Inhalation exposures are typically highest during removal of wood from the treatment vessel. But uses and imports of treated wood have been restricted.

In the EU, certain industries have been classified as high in terms of workers’ exposure to chromium(VI): manufacture of chemicals and chemical products, basic metals, fabricated metal products, including machinery and equipment, other transport equipment and furniture. Exposure risks are particularly high in SMEs. Small companies have been found to be at particular risk of lacking adequate control, especially in the manufacture of pigments and dyes, the formulation of metal treatment products, electroplating and wood dyeing.

Available evidence (e.g. from the CAREX database) indicates that sodium, potassium, calcium and ammonium chromates and dichromates have been identified as the most important in terms of workers’ exposures, a number of which are already regulated under REACH.\textsuperscript{72}

**Health effects**

The toxicity of chromium depends on the oxidation state, chromium(VI) being more toxic than chromium(III). In addition, chromium(VI) is more readily absorbed by both inhalation and oral routes. The respiratory tract is the primary target organ for inhaled chromium. Occupational exposure to chromium(VI) compounds has been associated with an increased risk of lung cancer and sinonasal cancer. The possible causation of stomach cancer is still an issue of controversy.\textsuperscript{73,74}

Ingestion of large amounts of chromium(VI) can lead to severe respiratory, cardiovascular, gastrointestinal, hepatic and renal damage, and potentially death.

---


Chromium(VI) compounds may cause other adverse health effects at comparable threshold levels, including nasal irritation, severe skin damage or renal toxicity. Chromium(VI) compounds are potent skin sensitisers in humans and can cause respiratory sensitisation.76 Single exposures to chromium(VI) compounds can cause irritation and inflammation of the nose and upper respiratory tract, and irritation of the skin with skin contact — and for chromic acid, burns to the skin, possibly leading to ulcers or eye damage from splashes. Repeated exposure to chromium(VI) compounds can cause damage to the nose, including ulcers and holes in the nasal septum, inflammation of the lungs, allergic reactions in the skin and respiratory tract, kidney damage, based on experimental data, and concerns about potential effects on reproduction, in both male fertility and the development of the unborn child. Chromium(VI) may cause occupational asthma in sensitised individuals.

**EU and IARC classification**

Chromium(VI) compounds with the exception of barium chromate and of compounds otherwise specified in Annex VI to the CLP Regulation have a harmonised classification as carcinogen 1B — may cause cancer by inhalation. Thirteen further chromium(VI) compounds have harmonised classification entries as carcinogen Group 1 under IARC classification.76

According to the classification provided by companies to ECHA in CLP notifications, chromium(VI) may cause cancer and may cause an allergic skin reaction.77

**Legislation**

Binding OELs for chromium(VI) compounds were last amended in 2017 with the first amendment to the CMD.78 Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with this directive by 17 January 2020. A transitional period until January 2025 has been introduced during which a higher limit value would apply. For the specific situation where the work activity concerns work involving welding or plasma cutting processes or similar such processes that generate fumes, an even higher transitional limit value should apply during that transitional period until January 2025, after which the generally applicable limit value would apply.

In 2003, in EU Directive 2003/02/EC, the Commission restricted the use of arsenic-containing wood preservatives. According to the directive, arsenic compounds may not be used in the preservation of wood and wood treated with arsenic compounds may not be put on the market unless the structural integrity of the wood is required for safety reasons and dermal contact with the wood by the general public is unlikely. This directive has meant that the use of CCA in wood preservatives has effectively ceased in the EU. The use of CCA solutions in the preservation of timber and import of CCA-treated timber is regulated by the Biocidal Product Regulation and is no longer permitted, and its use is further restricted under Annex XVII of the REACH Regulation.

Since 2006, chromium(VI) has been banned for certain uses (for instance in new vehicles or electronic equipment). Since 2007, coatings containing chromium(VI) have not been permitted under the EU End of Life Vehicles Directive and the Waste from Electrical and Electronic Equipment Directive. The EU’s RoHS Directive79 restricts chromium(VI) in all electrical and electronic products with very limited exceptions specified in the directive. The limit is 0.1%.

---

75 Recommendation from the Scientific Committee on Occupational Exposure Limits: Risk assessment for Hexavalent Chromium; SCOEL/SUM/86; December 2004: https://ec.europa.eu/social/BlobServlet?docId=3851&langId=en

European Agency for Safety and Health at Work – EU-OSHA
In October 2023, ECHA has received a mandate from the European Commission to prepare an Annex XV report for possible restriction of at least the chromium(VI) substances that are currently in entries 16 and 17 of the REACH Authorisation List (Annex XIV) (chromium trioxide and chromic acid). The number of workers with high level of exposure is likely to have declined further since then. A subset of chromium(VI) compounds (out of over 100) are listed in Annex XIV of the REACH Regulation and so are, or will be, subject to authorisation for continued use.
8. Cobalt

Cobalt is a silver-grey, bendable metal. It occurs in nature in a widespread but dispersed form in many rocks and soils. Cobalt is an important metal with many diverse industrial and military applications. The European Commission has created a list of critical raw materials\textsuperscript{80} for the EU, which is subject to a regular review and the 2023 update includes cobalt.\textsuperscript{81}

In 2016, the global demand for refined cobalt was around 98,000 tonnes, an amount that had almost tripled since 2000. The consumption in 2016 was estimated to be in: battery chemicals (lithium-ion (lithium-cobalt oxide (LCO)), lithium-nickel manganese cobalt oxides (NCM), lithium nickel cobalt aluminium oxides (NCA) cathode) and nickel-metal hydride (Ni-MH)/Ni-Cd (anode/cathode): 49%; superalloys (aerospace; land-based turbines/industrial gas turbines (GT); medical (prosthetics)): 18%; hard metals (cutting tools, mining, oil and gas drilling, etc.): 8%; ceramics/pigments: 6%; catalysts (oxidation (thermoplastic polymers production), hydro treating/desulphurisation (gas, oil, refining, petrochemicals), Fischer Tropsch process to convert carbon monoxide and hydrogen into liquid hydrocarbons): 5%; hard facing: 4%; tires/paint dryers: 4%; magnets: 3%; and others (electroplating, high-speed steels, agriculture/animal feed, synthetic diamonds): 3%.\textsuperscript{82}

\textbf{Mining and refinery of cobalt}

Cobalt is mainly mined as a by-product from copper and nickel mines. Both underground and surface mining technologies are used.

In the EU, cobalt is mined in Finland as a by-product of copper and nickel production. Refined cobalt is produced by several companies in Finland. Besides mined cobalt, the feed for refinery is imported as crude cobalt hydroxide and nickel matte as well as cobalt-bearing scrap from the cemented carbide, battery and catalyst industries.\textsuperscript{83}

\textbf{Use of cobalt}

According to the 2022 ECHA scientific report for OEL setting,\textsuperscript{84} the three main uses for cobalt and its inorganic compounds are battery production for electric vehicles, tablets and smartphones (57%), nickel-based alloy production (13%) and manufacturing tools (8%). Cobalt is also used to make magnets, corrosion- and wear-resistant alloys, high-speed steels, hard-metal and cobalt diamond tools, cobalt discs and other cutting and grinding tools, catalysts for the petroleum and chemical industries, drying agents for paints, varnishes and inks, ground coats for porcelain enamels, pigments, battery electrodes, steel-belted radial tyres, airbags in automobiles and magnetic recording media.

\textbf{Cobalt-containing alloys}

Its most common use is in superalloys,\textsuperscript{85} which are used primarily to make parts for aircraft gas turbine engines. Cobalt is used as an alloying element in the production of cobalt metal alloys of different grades. Cobalt is also an important component of steel when high strength is required, as it increases the tempering resistance of steel; high-strength steels (maraging steels) are used in the aerospace, machine tool and marine equipment industries. Cobalt-nickel alloys are used in jet engines, gas turbines, chemical processing, petroleum refining, marine, electronics and other industrial applications where common stainless steels may not provide adequate performance. Cobalt is ferromagnetic and is

\textsuperscript{80} Critical raw materials combine raw materials of high importance to the EU economy and of high risk associated with their supply.

\textsuperscript{81} For more information, see: https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en


\textsuperscript{83} European Commission, OELS 6 Study on collecting the most recent information on substances to analyse health, socio-economic and environmental impacts in connection with possible amendments of Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens, mutagens or reprotoxic substances at work. Draft final report (v3). Cobalt and inorganic cobalt compounds, November 2023 (unpublished).


\textsuperscript{85} Superalloys are alloys usually based on group VIIIA elements (iron, cobalt, nickel) developed for elevated temperature use, where relatively severe mechanical stressing is encountered and where high surface stability is frequently required.

---

European Agency for Safety and Health at Work – EU-OSHA
commonly alloyed with aluminium and nickel to produce magnets and varistors. The magnets are used for multiple applications, for example, in electric motors, guitar pickups, microphones, sensors, loudspeakers, medical instruments, generators and actuators. The substances used are cobalt metal, tricobalt tetraoxide and cobalt monoxide.

Other cobalt alloys include cobalt-chrome (Co-Cr) ones that are widely used as metal implants. Cobalt is also used to make artificial body parts such as hip and knee joints due to their wear resistance characteristics. In the dental and medical sectors, cobalt and cobalt alloys are used in dental alloys and implants (e.g. crowns and fillings), medical implants (e.g. stents, pacemakers), medical devices, and prosthetics (e.g. knee and hip replacements). Co-Cr alloys are used in orthopaedic and dental implants due to their biocompatibility, high resistance to corrosion and wear resistance.

**Hard-metal production and cobalt-containing tools**

Cobalt is essential for hard-metal tools. Cobalt is used as a binder in the production of hard metal (also referred to as cemented carbide and tungsten carbide). Metallic carbides are bound together or cemented by a soft and ductile metal binder, usually cobalt or nickel. The addition of cobalt to the carbide increases resistance to wear, hardness and mechanical strength, required for cutting tools, machine tools, engine components and other industrial applications. Hard-metal tools support various kinds of significant industries, such as tool manufacturing, steel and metal processing, construction, automotive, oil and gas, aerospace, food & beverage processing, medical, hygienic, wood processing, security, packaging, energy, transport technology, bar peeling and heavy machining. Hard metals have applications in tools for machining metals, drawing wires, rods and tubes, rolling or pressing, cutting various materials, drilling rocks, cement, brick, road surfaces and glass, and many other uses in which resistance to wear and corrosion are needed, such as high-speed dental drills, ballpoint pens and tyre studs.

Diamond tools are used increasingly to cut stone, marble, glass, wood and other materials and to grind or polish various materials, including diamonds. Although these tools are not composed of hard metal, as they do not contain tungsten carbide, they are often considered in the same category. They are also produced by powder metallurgy, whereby microdiamonds are impregnated in a matrix of compacted, extra fine cobalt powder. Consequently, the proportion of cobalt in bonded diamond tools is higher (up to 90%) than in hard metal.

**Use of its radioactive isotopes**

Cobalt has several artificial radioactive isotopes, the most important being Cobalt-60 ($^{60}$Co). Cobalt-60 is a beta and gamma emitter and is used in radiation therapy, imaging, level gauges, food irradiation and research. Workers at nuclear or irradiation facilities may therefore also be at risk. Cobalt is extracted from several mineral ores. $^{86}$

**Production of catalysts**

Cobalt metal and cobalt compounds are used in the manufacture of catalysts. Cobalt-containing catalysts are used in industrial applications such as the desulphurisation of natural gas. Beside these uses of catalysts, some organic cobalt compounds are used as catalysts in the plastics and detergents sectors. Cobalt substances used for catalysts are (some used as intermediates): cobalt metal, cobalt monoxide, cobalt dihydroxide, tricobalt tetraoxide, naphthenic acids cobalt salts, cobalt bis(2-ethylhexanoate), neodecanoic acid cobalt salt, cobalt(2+) propionate, cobalt di(acetate), cobalt sulphide, cobalt sulphate and cobalt dinitrate.

**Pigments and dyes**

Cobalt and cobalt compounds are used to produce colours (blue, purple, violet, green, turquoise, etc.) for inks and pigments. By altering the concentration of cobalt oxide and adding other metal oxides, many different colours can be created that are in turn used to colour ceramics and glass.

---

$^{86}$ This includes arsenide, sulphaarsenide (cobaltite), sulphide (chalococite, carrollite), arsenic-free cobalt-copper (heterogenite), lateritic and oxide ores.
**Cobalt compounds**

Cobalt carbonate is used in ceramics and as an animal feed supplement in trace amounts. Cobalt chloride is used as a humidity and water indicator, in electroplating, in the manufacture of vitamin B12, as a fertiliser and as a feed additive in trace amounts. Cobalt oxide is used in pigments for ceramics and glass, in fast drying paints and varnishes, in semiconductors, in enamel coatings on steel, and again as an animal feed additive in trace amounts. Cobalt sulphate is used in electroplating, in batteries, as a drying agent in inks and varnishes, in enamels and ceramics, and as feed. Cobalt sulphate is the usual source of water-soluble cobalt since it is the most economical salt and shows less tendency to deliquesce or dehydrate than the chloride or nitrate salts. It is used in storage batteries, in cobalt electroplating baths, as a drier for lithographic inks and varnishes, in ceramics, enamels and glazes to prevent discoloring, and in cobalt pigments for decorating porcelain. Cobalt compounds (e.g. cobalt diacetate, cobalt dichloride and cobalt sulphate) are used as dyes for the textile leather, wood and paper industries.

The use of the cobalt salts in the manufacture of pigments and dyes is relatively minor, estimated at significantly less than 100 tonnes per year representing less than 1% of the uses of the cobalt salts.

Cobalt sulphate and cobalt dinitrate are the most commonly used cobalt salts in the surface treatment sector, with some limited use of cobalt di(acetate). Cobalt salts are used in metal or metal alloy plating (mainly gold-cobalt and tin-cobalt plating) to enhance hardness and wear resistance and/or for metal colouring. Cobalt salts are used in the generation of ‘conversion layers’ (also called passivation), typically on zinc- or zinc alloy-coated metallic products for corrosion protection. The addition of cobalt salts is necessary if corrosion protection is required in warm or hot environments (e.g. engine spaces, brakes, gearboxes and in electrical parts in housings, etc.). Cobalt salts have important applications in the automotive, aerospace and defence sectors as well as for manufacture of fittings for window construction.

Cobalt plays an important role in renewable biogas technology. The fermentation involved in biogas production can be improved by adding small amounts of cobalt sulphate, cobalt chloride, cobalt carbonate or cobalt diacetate.

The five cobalt salts (cobalt sulphate, cobalt dichloride, cobalt dinitrate, cobalt carbonate and cobalt di(acetate)) are manufactured in and imported into the EU and used in a wide range of sectors and applications. The total volume manufactured and imported is estimated at 37,400 tonnes/year (30,000 are used in the EU and 7,400 are exported). An overview of exposure data in different tasks and occupations is provided in an ECHA restriction document from 2020. Approximately 8% of the total tonnage of the five cobalt salts are used in catalyst production. These substances are used as intermediates, and they are chemically transformed to produce catalyst precursors or active catalyst substances.

**Battery production**

Cobalt dinitrate and cobalt sulphate are used as intermediates in the manufacture of rechargeable batteries for the automotive market and for storage applications. Cobalt dinitrate and cobalt sulphate are transformed into cobalt hydroxide or tricobalt tetraoxide which are further used in the manufacture of cathodes for nickel-based batteries (Ni-Cd and Ni-MH) and for lithium-ion batteries (lithium cobalt oxide (LiCoO2-LCO), nickel manganese cobalt (NMC) or NCA). The most popular lithium-ion technology to power portable electronic devices like phones, laptops and tablets is the LCO battery that has a cathode composed of LiCoO2. The majority of modern electric vehicles use these battery chemistries in NMC batteries that have a cathode containing 10-20% cobalt. The demand for cobalt in electric vehicles and energy storage is expected to increase in the future.

**Occupational exposure**

Relevant exposure routes for cobalt are inhalation and oral. Inhalation absorption is highly dependent on the particle size of cobalt. As a metal, cobalt is not metabolised in the body. Excretion after inhalation

---

exposure is highly dependent on the solubility of the cobalt substance; the more soluble the substance is, the more rapidly it is eliminated via the lungs by transfer to the blood and excretion via urine and faeces.

Workers are often exposed to a mixture of cobalt compounds. Occupational exposure to aerosols containing cobalt metal or solubilised cobalt compounds may occur during the refining of cobalt, the production of alloys, at various stages in the manufacture of hard metals, in the maintenance and resharpening of hard-metal tools and blades, and during the manufacture and use of diamond tools containing cobalt, as well as in dentistry. Co-Cr materials are used for additive manufacturing (3D printing) of medical implants with high wear and corrosion resistance and high-temperature components in aerospace. Exposure by inhalation may take place by manufacture and handling of the powders and by the printing process.

However, only about 15% of cobalt produced is used in cemented carbides (hard metals) and diamond tooling, and there are many other potential sources of occupational exposure to cobalt. Workers in the hard-metal industry can have significant exposures to metallic cobalt particles in general in the presence but occasionally also in the absence of tungsten carbide. Exposure to metallic cobalt is also prevalent in the cobalt production industry. It should be noted that many workers inhaling different chemical species of cobalt may also be exposed to nickel, tungsten, chromium, arsenic, molybdenum, beryllium, silica and silicates, asbestos, nitrosamines, diamond powders and iron.

During the use of hard-metal tools (e.g. in drilling, cutting, sawing), the levels of exposure to cobalt or hard-metal dust are much lower than those found during their manufacture. However, the grinding of stone and wood with hard-metal tools and the maintenance and resharpening of these tools may release cobalt into the air at concentrations of several hundred micrograms per cubic metre. Coolants are used in the hard-metal industry during the process of grinding of hard-metal tools after sintering and in their maintenance and resharpening. During such operations, the continuous recycling of coolants has been shown to result in increased concentrations of dissolved cobalt in the metalworking liquid and, hence, a greater potential for exposure to (ionic) cobalt in aerosols released from these fluids. In addition, the process of depositing carbide coatings, by flame or plasma guns, on to softer substrates to harden their surfaces may also expose workers to hard metals.

Production and use of cobalt alloys gives rise to occupational exposure to cobalt in the welding, grinding and sharpening processes. Cobalt alloys may occur in welding, brazing, and plasma and thermal spraying processes in industrial and professional settings. Various welding methods are used such as gas-shielded arc (Metal active gas (MAG)) and oxy-acetylene welding processes. In these instances, exposure to fumes may be significant for workers via inhalation. Workers in metal thermal spraying were also found to inhale cobalt, chromium and nickel. Automotive repair shops may be significant emitters (to air) of cobalt.

Recycling of batteries for the purpose of recovering cobalt, nickel, chromium and cadmium may also expose workers. Cobalt will also be emitted to air, land and water during the mining or refining of nickel, copper, silver, lead and iron.

Exposure to catalysts may take place during the production of catalysts, the loading and unloading of catalysts from the reactor, as well as recycling and recovery of catalysts.

About 113,000 (67,000-177,000) workers were estimated to be exposed to cobalt and inorganic cobalt compounds within the scope of the CMRD at exposure levels relevant for the impact assessment for the sixth amendment to the CMRD. The main sectors or activities were manufacture of tools (26.5% of total exposed workforce), machining (22.1% of total), ceramics (6.6%), surface treatment of metals (4.6%), vehicles (4.6%), biogas production (4.8%), and medical and dental devices (4.4%).

89 Cobalt, nickel and chromium release from dental tools and alloys: https://pubmed.ncbi.nlm.nih.gov/23844864/
91 European Commission, OELS 6 Study on collecting the most recent information on substances to analyse health, socioeconomic and environmental impacts in connection with possible amendments of Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens, mutagens or reprotoxic substances at work. Draft final report (v3). Cobalt and inorganic cobalt compounds, November 2023 (unpublished).
Health effects

Several reports addressing cancer risks among workers in hard-metal production facilities provided evidence of an increased lung cancer risk related to exposure to hard-metal dust containing cobalt and tungsten carbide. A more recent IARC report from 2023\footnote{International Agency for Research on Cancer. (2023). Cobalt, antimony compounds, and weapons-grade tungsten alloy. IARC Monographs on the identification of carcinogenic hazards to humans (Vol. 131). https://publications.iarc.fr/Book-And-Report-Series/Iarc-Monographs-On-The-Identification-Of-Carcinogenic-Hazards-To-Humans/Cobalt-Antimony-Compounds-And-Weapons-grade-Tungsten-Alloy-2023} concluded that the evidence in humans was inadequate regarding the carcinogenicity of cobalt metal (without tungsten carbide or other metal alloys) and non-metallic forms of cobalt. Among the available human cancer studies, the studies of exposures to cobalt in the hard-metal industry did not permit separation of cobalt’s effects from those of the cobalt and tungsten carbide composite, or other known or suspected lung carcinogens, in examining lung cancer risk, and other occupational studies were either confounded by other known lung carcinogens or did not show associations of cobalt with lung cancer.

Cobalt may affect the heart, thyroid, liver and kidneys. Cobalt metal and several cobalt compounds have a harmonised classification as skin sensitiser and respiratory sensitiser. The skin sensitising properties of cobalt are well known. Exposure to cobalt may lead to allergic contact dermatitis, particularly in hard-metal workers. Urticarial reactions have also been described. Cross-reaction with nickel (as well as co-sensitisation) is frequent. The dermal effects of cobalt may occur with all forms of cobalt, that is, cobalt metal and other cobalt compounds, such as salts. Metallic cobalt-containing particles may cause irritation of the upper and lower airways leading to rhinitis, sinusitis, pharyngitis, tracheitis or bronchiolitis, but the main diseases of concern are bronchial asthma and a fibrosing alveolitis known as hard-metal lung disease (also called ‘cobalt lung disease’ or interstitial lung disease). Exposure to cobalt compounds is an established cause of obstructive lung disease/asthma, called cobalt-asthma, while exposure to cobalt-containing hard metal is an established cause of parenchymal lung disease, interstitial pneumonitis, and progressive pulmonary fibrosis, called ‘hard-metal disease’. Bronchial asthma has been described in workers exposed to various forms of cobalt, that is, not only in workers exposed to hard-metal dust but also in those exposed to ‘pure’ cobalt particles, as well as in subjects exposed to other cobalt compounds, such as cobalt salts. Occupational asthma is more frequent than fibrosing alveolitis in hard-metal workers or workers exposed to cobalt dust, but occasionally the two conditions co-exist.

Hard-metal lung diseases may also have a bearing on the risk of lung cancer, because fibrosing alveolitis and lung cancer may be related mechanistically. In addition to cases of severe parenchymal lung disease in diamond polishers, milder respiratory effects, including irritation and decreases in lung function, have been described in diamond polishers.

Cobalt metal and inorganic cobalt compounds show reproductive toxicity, including significant effects on male reproductive system and fertility.

EU and IARC classification

Cobalt and several inorganic cobalt compounds have a harmonised classification for carcinogenicity according to Annex VI of the CLP Regulation (carcinogen 1A or B).

According to the harmonised classification and labelling approved by the EU, cobalt may cause cancer, may damage fertility, is suspected of causing genetic defects, may cause an allergic skin reaction, and may cause allergy or asthma symptoms or breathing difficulties if inhaled. It is classified as carcinogen 1B (may cause cancer).\footnote{ECHA substance infocard - cobalt: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.028.325}

The five cobalt salts cobalt sulphate, cobalt dichloride, cobalt dinitrate, cobalt carbonate and cobalt di(acetate) have a harmonised classification under the CLP Regulation as carcinogen 1B (may cause cancer) and Mutagen 2 (suspected of causing genetic defects). In addition, they are classified as category 1 skin and respiratory sensitisers (may cause an allergic skin reaction; may cause allergy or asthma symptoms or breathing difficulties if inhaled).

For cobalt oxide, the classification provided by companies to ECHA in REACH registrations identifies that it is fatal if inhaled, is toxic if swallowed, may cause cancer, may damage fertility or the unborn
child, and may cause allergy or asthma symptoms or breathing difficulties if inhaled.\(^{94}\) For cobalt sulphate and cobalt dichloride, the harmonised classification and labelling approved by the EU indicates they may cause cancer by inhalation, may damage fertility, are harmful if swallowed, are suspected of causing genetic defects, may cause an allergic skin reaction, and may cause allergy or asthma symptoms or breathing difficulties if inhaled.\(^{95,96}\) According to the harmonised classification and labelling approved by the EU, cobalt carbonate may cause cancer by inhalation, may damage fertility, is suspected of causing genetic defects, may cause an allergic skin reaction, and may cause allergy or asthma symptoms or breathing difficulties if inhaled.\(^{97}\)

Cobalt metal with tungsten carbide was classified as probably carcinogenic to humans (Group 2A) by the IARC in 2006.\(^{98}\) In a more recent evaluation in the above-mentioned 2023 IARC report, cobalt metal (without tungsten carbide or other metal alloys) was classified as probably carcinogenic to humans (Group 2A). Soluble cobalt(II) salts were classified as probably carcinogenic to humans (Group 2A). Cobalt(II) oxide was classified as possibly carcinogenic to humans (Group 2B).

Cobalt(II,III) oxide and cobalt(II) sulphide, as well as other cobalt(II) compounds, were considered not classifiable as to their carcinogenicity to humans (Group 3).

**Legislation**

A binding EU OEL value for cobalt and inorganic cobalt compounds is currently under discussion. On request of the European Commission, the Committee for Risk Assessment (RAC) developed an opinion on the basis of a scientific report submitted by ECHA. The RAC opinion includes a recommendation to the Advisory Committee on Safety and Health at Work (ACSH) for OEL setting and the amended scientific report is annexed to the document. A background study will provide the basis for an impact assessment report to accompany a potential proposal to amend the CMRD.

Several EU Member States have established OEL values for cobalt and its compounds, including inorganic ones. Some Member States have additionally established short-term exposure limit values. Four EU Member States have established biological exposure limit values for cobalt and cobalt compounds in urine.

There are 42 substances considered registered under REACH for cobalt and inorganic cobalt compounds. For 34 of these substances, tonnage information is available as part of a REACH registration. These include 29 substances with full registrations, and five substances only registered as an intermediate. Five cobalt compounds had been recommended for inclusion in Annex XIV in the third recommendation of 20 December 2011: cobalt(II) sulphate, cobalt dichloride, cobalt(II)dinitrate, cobalt(II) carbonate and cobalt(II) diacetate. ECHA submitted an Annex XV dossier, proposing restrictions of the manufacture, placing on the market or use of a substance within the EU for the following soluble cobalt salts: cobalt sulphate, cobalt dichloride, cobalt dinitrate, cobalt carbonate and cobalt di(acetate), but the restrictions procedure was terminated in April 2022 and an OEL for professional use was deemed a better measure.

---

\(^{96}\) ECHA substance infocard - cobalt dichloride: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.028.718
\(^{97}\) ECHA substance infocard - cobalt carbonate: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.007.429
9. Diesel engine exhaust emissions

Diesel exhaust is a process-generated mixture that originates from combustion in fuel-powered equipment and vehicles. Diesel fuel is used in most large engines, including those used in many trucks, buses, trains, construction and farm equipment, generators, ships and in some cars.

Diesel exhaust is made up of two main parts: gases and soot (particles). Each of these, in turn, is made up of many different substances. The gas portion of diesel exhaust is mostly carbon dioxide, carbon monoxide, nitric oxide, nitrogen dioxide, sulphur oxides and hydrocarbons, including polycyclic aromatic hydrocarbons (PAHs). The soot (particulate) portion of diesel exhaust is made up of particles such as carbon, organic materials (including PAHs), and traces of metallic compounds. Both the gases and the soot of diesel exhaust contain PAHs.

Diesel engine exhaust emissions vary in their chemical composition and particle size distribution depending on engine types, engine operating conditions, fuel formulations, lubricating oil, additives and emission control systems. They also vary between on-road and non-road engines. The qualitative and quantitative composition of the diesel engine exhaust emissions has changed during the last years, beginning from the early 1990s, due to the introduction of stringent emission regulations in the EU. This triggered the development and application of new technology for diesel engines with changes in (the composition of) particulate matter (PM) and gaseous constituents in the exhaust.

**Occupational exposure**

People with some of the highest work exposures include truck drivers, toll booth workers, miners, forklift drivers and other heavy machinery operators, railroad and dock workers, and garage workers and mechanics. Some farm workers also spend a lot of time around diesel exhaust. Exposure to diesel exhaust may be higher when traveling on roads with heavier truck or bus traffic. Commuting for work is also a potential source of diesel exhaust exposure.

Workers may either be exposed because they operate equipment that has a diesel engine or because their work takes them into environments where diesel engines are operating.

According to the studies for the impact assessment of the EU legislative proposal for an OEL, it is estimated that there are 3.7 million workers in the EU potentially exposed to diesel exhaust emissions above background level. The number of people in the EU who were estimated to ever be occupationally exposed is projected to increase from about 12 million in 2010 to almost 20 million in 2060.

**Health effects**

Diesel engine emissions contain a complex mixture of gases, vapours, liquid aerosols and particulate matter which are the products of combustion and can be hazardous to health. Some of these components are known carcinogens (e.g. PAHs, formaldehyde, 1,3-butadiene and benzene), and others are not (e.g. carbon monoxide, carbon dioxide and oxides of nitrogen).

There is sufficient evidence of the carcinogenicity of diesel engine exhaust emissions arising from the combustion of diesel fuel in compression ignition engines.

Lung cancer is the major cancer thought to be linked to diesel exhaust. Several studies have also looked for possible links between diesel exhaust and other cancers, including cancers of the bladder, larynx (voice box), oesophagus, stomach and pancreas, and blood system cancers such as lymphomas and leukaemias.

---


The two cancers most clearly linked to diesel exhaust are lung and bladder cancer. The critical effect of traditional diesel engine exhaust emissions in rats is pulmonary cancer, which is considered to be the consequence of inflammation and genotoxicity being primarily induced by particulate matter. Lung toxicity of newest technology diesel engine exhaust however results primarily from NO\textsubscript{2} exposure. Consequently, for traditional diesel exhaust, the OEL would require control of particulate matter emissions, and for new types of engines, it would also require control of NO\textsubscript{2}, according to SCOEL.\textsuperscript{103}

**EU and IARC classification**

Diesel engine exhaust emissions are process-generated and therefore not subject to classification in accordance with Regulation (EC) No 1272/2008. In Annex I of Directive 2019/130 (a substance, mixture or process referred to in Annex I to this directive as well as a substance or mixture released by a process referred to in that annex is a carcinogen according to the CMD), ‘Work involving exposure to diesel engine exhaust emissions’ is mentioned.

Diesel engine exhaust has been classified by the IARC as carcinogenic to humans (Group 1) and the IARC has specified that while the amount of particulates and chemicals are reduced in the newer types of diesel engines, it is not yet clear how the quantitative and qualitative changes will translate into altered health effects. The IARC has also specified that it is common to use elemental carbon, which makes up a significant proportion of those emissions, as a marker of exposure.\textsuperscript{104}

**Legislation**

Binding OELs for diesel exhaust were last set in 2019 with the second amendment to the CMD.\textsuperscript{105} Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with this directive by 21 February 2021. However, the limit value for diesel engine exhaust emissions should apply since 21 February 2023. For underground mining and tunnel construction, the limit value shall apply from 21 February 2026.


10. **Diethyl sulphate/dimethyl sulphate**

**Diethyl sulphate** is manufactured from ethylene and sulphuric acid. It occurs as a colourless, oily liquid with a faint peppermint odour and is corrosive to tissue and metals.

**Dimethyl sulphate** is a colourless oily liquid, odourless to a faint onion-like odour. It is very toxic by inhalation and a combustible liquid with a flash point of 182 °F. It is slightly soluble in water and decomposed by water to give sulfuric acid with evolution of heat. It is corrosive to metals and tissue. It is a potent methylating agent.

**Use of diethyl sulphate**

It is used principally as an intermediate (potent ethylating agent) in the manufacture of dyes, pigments and textile chemicals, and as a dye-set agent in carbonless paper and as a finishing agent in textile production. It is an intermediate in the indirect hydration (strong acid) process for the preparation of synthetic ethanol from ethylene. Diethyl sulphate is used as an alkylating agent to prepare ethyl derivatives of phenols, amines and thiols. Smaller applications are in agricultural chemicals, in household products, in the pharmaceutical and cosmetic industries, as a laboratory reagent, as an accelerator in the sulfation of ethylene and in some sulfonation processes. The most probable routes of exposure to diethyl sulphate are by dermal contact or inhalation during its production or use. Diethyl sulphate is manufactured in and/or imported into the European Economic Area at ≥ 1 to < 10 tonnes per year.

**Use of dimethyl sulphate**

**Dimethyl sulphate** has been produced commercially since at least the 1920s. Dimethyl sulphate is mainly used as a methylating agent for converting active-hydrogen compounds such as phenols, amines and thiols to the corresponding methyl derivatives in the manufacturing of dyes, perfumes and pharmaceuticals, for the separation of mineral oils, and for the analysis of automobile fluids. Also, its sulphating properties are applied in the manufacturing of various products (e.g. dyes and fabric softeners, etc.). Formerly, dimethyl sulphate was used as a war gas. According to the United States Environmental Protection Agency, exposure to dimethyl sulphate is primarily occupational. Exposure to dimethyl sulphate may occur during its manufacture and its use as a methylating agent.

Dimethyl sulphate is registered under the REACH Regulation and, according to the registration, is manufactured in and/or imported into the European Economic Area for intermediate use only. Therefore, no information on the production volume is available. According to registration, it is used at industrial sites and in manufacturing.

**Health effects**

Diethyl sulphate is a strong alkylating agent that ethylates DNA, causing both somatic and germ cell mutations, and is therefore genotoxic. Inhalation of diethyl sulphate has the potential to be fatal and can induce nausea or vomiting. Swallowing this substance could also be fatal or lead to nausea, vomiting, or severe abdominal pain. Contact with or absorption through the skin also has potential to be fatal and can cause severe burns.

Epidemiological studies focused on laryngeal, buccal and pharyngeal cancers, as well as brain cancers.

Dimethyl sulphate is corrosive or irritant to the skin, eyes and respiratory tract of exposed people, and may result in death caused by respiratory failure. Dimethyl sulphate can be absorbed by all routes (oral, respiratory and dermal) but data are limited. It is toxic after oral, dermal and inhalation exposure. The Health Council of the Netherlands considered it a potent carcinogen. Epidemiological studies focus on lung cancer.\(^{106}\)

Acute (short-term) exposure of humans to the vapours of dimethyl sulphate may cause severe inflammation and necrosis of the eyes, mouth and respiratory tract. Acute oral or inhalation exposure to dimethyl sulphate primarily damages the lungs but also injures the liver, kidneys, heart and central nervous system (CNS), while dermal contact with dimethyl sulphate may produce severe blistering in

Humans. Human data on the carcinogenic effects of dimethyl sulphate are inadequate. Tumours have been observed in the nasal passages, lungs and thorax of animals exposed to dimethyl sulphate by inhalation.107

**EU and IARC classification**

According to the harmonised classification and labelling approved by the EU, diethyl sulphate causes severe skin burns and eye damage, may cause genetic defects, may cause cancer, is harmful if swallowed, is harmful in contact with skin and is harmful if inhaled. Additionally, the classification provided by companies to ECHA in REACH registrations identifies that diethyl sulphate is toxic in contact with skin and causes serious eye damage. Diethyl sulphate is classified as a carcinogen 1B.

According to the harmonised classification and labelling approved by the EU, dimethyl sulphate is fatal if inhaled, is toxic if swallowed, causes severe skin burns and eye damage, may cause cancer, is suspected of causing genetic defects and may cause an allergic skin reaction. Additionally, the classification provided by companies to ECHA in REACH registrations identifies that dimethyl sulphate may cause genetic defects and causes serious eye damage. Dimethyl sulphate is a carcinogen 1B.

In its evaluation published 1999, the IARC concluded that there was inadequate evidence for the carcinogenicity in humans of diethyl sulphate and sufficient evidence for the carcinogenicity in experimental animals of diethyl sulphate. Diethyl sulphate was classified as probably carcinogenic to humans (Group 2A). Diethyl sulphate is a strong alkylating agent that ethylates DNA. As a result, it is genotoxic in virtually all test systems examined including induction of potent effects in somatic and germ cells of mammals exposed in vivo.

The IARC also concluded in its monograph in 1999 that there was inadequate evidence for the carcinogenicity in humans of dimethyl sulphate, but sufficient evidence for the carcinogenicity in experimental animals of dimethyl sulphate and classified dimethyl sulphate as probably carcinogenic to humans (Group 2A).108

**Legislation**

Diethyl sulphate is an SVHC and included in the Candidate List for authorisation. Diethyl sulphate is registered under the REACH Regulation.109

Dimethyl sulphate is an SVHC and included in the Candidate List for authorisation. Industrial accident prevention and reporting requirements have been established for this substance under the Seveso Directives.110

---

107 See: [https://www.epa.gov/sites/default/files/2016-09/documents/dimethyl-sulfate.pdf](https://www.epa.gov/sites/default/files/2016-09/documents/dimethyl-sulfate.pdf)


109 ECHA substance infocard - diethyl sulphate: [https://echa.europa.eu/es/substance-information/-/substanceinfo/100.000.536](https://echa.europa.eu/es/substance-information/-/substanceinfo/100.000.536)

110 ECHA substance infocard - dimethyl sulphate: [https://echa.europa.eu/es/substance-information/-/substanceinfo/100.000.963](https://echa.europa.eu/es/substance-information/-/substanceinfo/100.000.963)
11. Epichlorohydrin

Epichlorohydrin (1-chloro-2,3-epoxypropane) is an organochlorine compound and an epoxide. It is a colourless liquid with a pungent, garlic-like odour. Epichlorohydrin is a highly reactive electrophilic compound and is used in the production of glycerol, plastics, epoxy glues and resins, epoxy diluents and elastomers.

**Use of epichlorohydrin**

Epichlorohydrin is mainly used in the production of epoxy and phenoxy resins, manufacture of glycerine, curing of propylene-based rubbers, as a solvent for cellulose esters and ethers, and in resins with high wet-strength for the paper industry. It is also used in pH regulators and water treatment products and laboratory chemicals and in health services and scientific research and development. Release to the environment can occur from industrial use (thermoplastic manufacture). It is used in paper chemicals and dyes, washing and cleaning products, cosmetics and personal care products, and oil and gas exploration or production products. Other release of epichlorohydrin is likely to occur from indoor use (e.g. machine wash liquids/detergents, automotive care products, paints and coatings or adhesives, fragrances and air fresheners) and outdoor use as a processing aid.

**Occupational exposure**

According to the EU studies for OEL setting of 2017, there were 15 high-volume (> 1,000 tonnes per year) producers or importers of epichlorohydrin within the EU in the following Member States: Germany (4), Netherlands (3), UK (2), Italy (2), Sweden (1), Finland (1), Austria (1) and Belgium (1). Annual production in the EU was estimated at around 360,000 tonnes per year, while annual global production was estimated at around 900,000 tonnes. The total estimated number of exposed workers in the EU was 43,800.

Workers’ inhalation and dermal exposures were assessed to be controlled via the use of closed systems with engineering controls such as vapour return lines during product transfer, the dry disconnect style of fittings for transfer hoses and automated sampling systems. PPE is also used to reduce exposure. Significant exposures are therefore likely to occur only during maintenance activities, or during accidental releases.

**Health effects**

Epichlorohydrin is a genotoxic carcinogen without a threshold. SCOEL identified for epichlorohydrin the possibility of significant uptake through the skin. SCOEL concluded that it was not possible to derive a health-based exposure limit value for it as a non-threshold carcinogen and has recommended avoiding occupational exposure.

Besides its probable carcinogenicity to humans, epichlorohydrin in liquid form has been found to cause skin burns and the vapour can cause irritation of the eyes, nose and throat.

**EU and IARC classification**

Epichlorohydrin meets the criteria for classification as carcinogenic (category 1B) in accordance with Regulation (EC) No 1272/2008 and therefore is a carcinogen as defined in Directive 2004/37/EC. It has

---


114 Recommendation from the Scientific Committee on Occupational Exposure Limits for epichlorohydrin, SCOEL/SUM/169, September 2011: http://ec.europa.eu/social/BlobServlet?docId=7304&langId=en
a CLP harmonised classification, and is classified as toxic if inhaled, toxic in contact with skin and toxic if swallowed; it causes severe skin burns and eye damage and may cause an allergic skin reaction.\textsuperscript{115} Epichlorohydrin was classified by the IARC as probably carcinogenic to humans (Group 2A).\textsuperscript{116}

**Legislation**

Binding OELs for epichlorohydrin were last set in 2019 with the second amendment to the CMD (now CMRD).\textsuperscript{117} Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with this directive by 21 February 2021.

\textsuperscript{115} ECHA substance infocard - 1-chloro-2,3-epoxypropane: [https://echa.europa.eu/es/substance-information/-/substanceinfo/100.003.128](https://echa.europa.eu/es/substance-information/-/substanceinfo/100.003.128)


12. Ethylene oxide

Ethylene oxide (C₂H₄O) is a flammable gas with a slightly sweet odour. A unique feature for ethylene oxide is that low levels of this chemical are produced endogenously by both the human and animal organism, and ethylene oxide represents therefore a physiological body constituent.

Use of ethylene oxide

Ethylene oxide is used for producing detergents, thickeners, solvents, plastics, and various organic chemicals such as ethylene glycol, ethanolamines, simple and complex glycols, polyglycol ethers and other compounds. It is also used in the manufacture of consumer goods such as anti-freeze solvents and cosmetics. Conversion of ethylene oxide to ethylene glycols represents a major use for ethylene oxide in most regions (about 44% in Europe). A very small proportion (0.05%) of the annual production of ethylene oxide is used directly in the gaseous form as a sterilising agent, fumigant and insecticide, either alone or in non-explosive mixtures with nitrogen, carbon dioxide or dichlorofluoromethane. In hospitals and the medical equipment industry it is used as a surface disinfectant to replace steam in the sterilisation of heat-sensitive tools and equipment, such as disposable plastic syringes. It is also used to sterilise drugs, packaging materials, foods, books, museum artefacts, scientific equipment, clothing, furs, railcars, aircraft, beehives and other items.

According to the impact assessment accompanying the legislative proposal for OEL setting in 2016, about 3.8 million tonnes of ethylene oxide were produced in Europe every year. The majority is used in the manufacturing of ethylene oxide derivates such as ethylene glycols, which are used in the production of consumer goods. The global market for ethylene oxide was expected to continue expanding.

Occupational exposure

It was estimated that approximately 15,600 workers in the EU were potentially exposed. There were two countries where the production and/or use of this chemical agent was concentrated, and the numbers of exposed workers were the highest (Germany, UK). An estimate of number of exposed workers by country is included in the impact assessment document for the first amendment of the CMD (p. 155).

Health effects

The acute (short-term) effects of ethylene oxide in humans consist mainly of CNS depression and irritation of the eyes and mucous membranes. Acute inhalation exposure of workers to high levels of ethylene oxide has resulted in nausea, vomiting, neurological disorders, bronchitis, pulmonary oedema and emphysema. Dermal or ocular contact with solutions of ethylene oxide has caused irritation of the skin and eyes in humans. Tests involving acute exposure of animals have shown ethylene oxide to have high acute toxicity from inhalation exposures.

Major effects observed in workers exposed to ethylene oxide at low levels for several years are irritation of the eyes, skin and respiratory passages and effects on the nervous system (e.g. headache, nausea, memory loss, numbness). There also is some evidence linking ethylene oxide exposure to reproductive effects.

---


Lymphoma and leukaemia are the cancers most frequently reported to be associated with occupational exposure to ethylene oxide. Stomach and breast cancers may also be associated with ethylene oxide exposure.

**EU and IARC classification**

Ethylene oxide is classified according to the criteria in the CLP Regulation as a carcinogen category 1B based on limited human epidemiological evidence and other data that it may cause leukaemia. Where there is the possibility of a significant uptake via dermal exposure, SCOEL recommended that any OEL be accompanied by a ‘skin notation’. This and the fact that ethylene oxide is a skin irritant would normally result in employers taking steps to avoid skin contact as a part of routine OSH risk control.

According to the harmonised classification and labelling (ATP14) approved by the EU, this substance is toxic if swallowed, causes severe skin burns and serious eye damage, is toxic if inhaled, may cause genetic defects, may cause cancer, may damage fertility and is suspected of damaging the unborn child, causes damage to organs through prolonged or repeated exposure, is an extremely flammable gas, may cause respiratory irritation, and may cause drowsiness or dizziness.\(^{121}\)

Ethylene oxide has been classified as carcinogenic to humans (Group 1) by the IARC.\(^{122}\)

**Legislation**

Binding OELs for ethylene oxide were set in 2017 with the first amendment to the CMD (now CMRD).\(^{123}\) Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with this directive by 17 January 2020.

\(^{121}\) ECHA substance infocard - ethylene oxide: [https://echa.europa.eu/es/substance-information/-/substanceinfo/100.000.773](https://echa.europa.eu/es/substance-information/-/substanceinfo/100.000.773)


13. **Formaldehyde**

Pure formaldehyde is a pungent-smelling colourless gas that polymerises spontaneously into paraformaldehyde, hence it is stored as an aqueous solution (*formalin*). Formaldehyde at room temperature is a volatile gas with a high vapour pressure and is unstable. Formaldehyde is dissolved in water to produce methanediol. Formaldehyde aqueous solutions are known as formalin (in 2013, over 7 million tonnes were produced in the EU) and methanol can be added to the solution to prevent polymerisation. Formaldehyde is also used as a monomer in the synthesis of paraformaldehyde (polymer) and is also available as a solid crystal (trioxane).

Formaldehyde is an important precursor to many other materials and chemical compounds. Formalin is mostly used as an intermediate in the manufacturing of other substances (e.g. formaldehyde-based resins that are, in turn, used in the production of a number of articles, including wood-based products), as a disinfectant for industrial and professional uses, and as a preservative in funeral homes and medical labs.

Formaldehyde is also a naturally occurring chemical that is formed endogenously in mammals, including humans. In addition, common non-occupational exposures include combustion processes, which include tobacco smoking, and emissions from building materials.

**Formaldehyde releasers** are substances that release formaldehyde during use. Release may be intentional (e.g. the case when formaldehyde is released by another substance because of its biocidal properties) or unintentional (e.g. due to degradation of another substance). Substances that might release formaldehyde include urea-formaldehyde (UF) resins, melamine-formaldehyde (MF) resins, phenol-formaldehyde (PF) resins, polycetal resins and polyacetal (also called polyoxymethylene (POM)). Formaldehyde can also be used in the form of a polymerised solid — paraformaldehyde, which tends to be favoured in industrial applications in plants that are located at long distances from formaldehyde manufacturing plants due to its lighter weight and lower shipping costs.

**Use of formaldehyde**

Formaldehyde is used in a wide array of economic sectors, ranging from agriculture, forestry and fishing, manufacturing of food products, manufacture of textiles, manufacture of leather and related products, manufacture of wood and products of wood and cork, except furniture, manufacture of pulp, paper and paper products, manufacture of chemicals and chemical products, manufacture of basic pharmaceutical products and pharmaceutical preparations, manufacture of rubber and plastic products, and so on to professional, scientific and technical activities, human health, and funeral and related activities. Formaldehyde and formaldehyde releasers are also widely used in the automotive industry, activities such as building and construction work, and the manufacturing of leather and fur. Formaldehyde and some formaldehyde releasers can also be used as a preservative in some foods and in products such as antiseptics, medicines and cosmetics.

Operations where exposure could occur are during the manufacturing process, which includes spraying, processing, mixing/blending, assembly, dipping/pouring and cutting/sanding.¹²⁴

According to ECHA, formaldehyde is registered under the REACH Regulation and is manufactured in and/or imported into the European Economic Area at ≥ 1 million tonnes per year. It was estimated that about 134,000 small, 8,400 medium and 9,000 large enterprises have workers exposed to formaldehyde to some degree in the EU. Member States with more than 10,000 enterprises using formaldehyde are Germany, Spain, France, Italy, and Poland. More information on specific uses of formaldehyde is provided in the staff working document for the impact assessment of the third amendment to the CMD (now CMRD).¹²⁵ An overview table is provided on pp. 143-145 of the report.


Agriculture, forestry and fishing

Formaldehyde is used in slow-release fertilisers and in urea treated with formaldehyde as a stabiliser in fertiliser manufacturing. Formaldehyde has also been identified as being used in fish farms that are stocked with brown and rainbow trout.

Formaldehyde is used as a veterinary biocidal agent in the poultry sector and is used as a fumigant due to its capability to destroy microorganisms on eggs, egg cases, chick boxes and hatchery equipment. It can be useful for controlling zoonoses in hatcheries. Formaldehyde vapour is easily generated from formalin or paraformaldehyde for use as a disinfectant is efficient for treating buildings.

Formaldehyde is also used as a disinfectant in greenhouses between crop cycles and in foot baths for treating Mortellaro disease in dairy cows.

Food industry

Formaldehyde is used in the manufacturing of food products as a bacteriostatic agent, for example in foods such as cheese, in the preservation of dried foods, for disinfecting containers, in the preservation of fish and certain oils and foods, and in the modification of starch for cold swelling. Formaldehyde is also used in sugar beet processing, where it is used as a biocidal agent in saccharose extraction from beetroots.

Health sector and embalming

Formaldehyde and its releasers also have applications in pathology and embalming, for their sterilising, preserving and stabilising properties. Formaldehyde is used for the following applications in the healthcare sector:

- Health services: Cleaning medical equipment, surfaces and environments; used to fix and maintain specimens and tissue samples; used as a tissue preservative (typically 10% concentration) and as an embalming agent.
- Dentistry: Antiseptics and disinfectants, e.g. composite resins replacing amalgam and root canal fillings.
- Schools and universities: Used as a preservative for specimen and tissue samples.
- Funeral homes: For embalming.

Operations where formaldehyde exposure could occur include in operating rooms and pathology laboratories and for the uses listed above.

Scientific research and development, laboratories

Formaldehyde is used in the electrophoresis (method to separate mixtures by size) of RNA and as a laboratory reagent in control laboratories, as well as in the synthesis of chelating agents and pyridines and for health research.

Chemicals and plastics manufacturing

Formaldehyde is also an intermediate used in the synthesis of industrial chemicals and plastics. Formaldehyde is also used in the manufacturing of the following chemical products:

- Fertilisers: Exposure could occur during fertiliser production (during cleaning/maintenance, sampling and general operation) and, in some cases, where formaldehyde is used as a stabiliser as this may be partially sprayed over the final product.
- Methylene dianiline (MDA) and diphenyl methane diisocyanate (MDI), where formaldehyde is used as an intermediate. MDA is used in the manufacture of MDI which is used in insulation foams, paints and coatings, adhesives for wood panels, automotive seats, bedding and mattresses (8% of formaldehyde in the EU is used for this purpose).
- Paints, varnishes and similar coatings, printing inks and mastics: UF resins, MF resins and PF resins are used as binding agents. The applications of adhesives and coatings are also listed as a use for professional workers in the REACH registration dossier.
- Soaps and detergents, cleaning and polishing preparations, perfumes and toilet preparations: Formaldehyde can be used for preservation applications, household cleaning agents and in nail hardeners among others and is present in low concentrations.
Explosives: Formaldehyde can also be used in the manufacture of explosives such as RDX. In this application, formaldehyde is reacted with ammonia to produce hexamine (which can then be used in explosives).

Exposure to formaldehyde during manufacturing of chemicals and chemical products can occur during process control and sampling, cleaning/service/repairs and filter changing among others.

**Manufacture of basic pharmaceutical products and pharmaceutical preparations**

In the pharmaceutical sector, formaldehyde is used in the manufacture of gelatine capsules. It is also used as an inactivating agent in vaccines, where it is used to inactivate toxins from bacteria and viruses.

**Textile industry**

In the manufacture of textiles, formaldehyde-based resins are used. These resins are used to bind dyes and pigments to fabrics and also to prevent colours from running when clothes are washed. UF and MF resins can also be used in textile manufacturing for making clothes stain and wrinkle resistant.

**Manufacture of leather and related products**

Formaldehyde is used in tanneries and as a preservative for preventing hides from decomposing.

**Manufacture of wood and products of wood and cork**

The majority of formaldehyde produced in the EU is used to manufacture resins. The primary use is in the production of UF resins (50% of EU consumption), MF resins (10% of EU consumption) and PF resins (12% of EU consumption). Polyacetyl (POM) resins account for 8% of the EU formaldehyde market and is a growing market as POMs are self-lubricating thermoplastics for metal components and are used in a variety of sectors such as gears, housings and bearings.

The primary use of formaldehyde-based resins is in the manufacture of wood-based materials. In particular, UF and PF resins are used in the manufacture of wood and products of wood and cork. The primary application of the resins is as a ‘glue resin’ in wood panels and wooden plates. UF and PF resins are also used as ‘glue resins’ in furniture manufacturing.

**Automotive industry and aircraft**

Formaldehyde-based resins are used in many automotive applications and aircraft applications.

**Construction**

Formaldehyde-based foams (UF and PF) are used as building materials and insulator materials and can also be used as an adhesive in mineral wools that have applications as thermal insulators.

**Manufacture of fabricated metals, except machinery and equipment**

Formaldehyde can be used as a preservative in metal remover fluids, anticorrosive agents and metalworking agents; these products may also release formaldehyde. The use of formaldehyde releasers for metal working fluids is covered in Product type 13 of the Biocidal Products Regulation (preservatives). Exposure can occur during metal finishing and plating. Exposure can also occur in foundries, as when sand is hardened, formaldehyde-based resins are used.

**Manufacture of electrical equipment**

POM resins are also used in powder injection moulding technology. POM resins are also used in the manufacture of electrical and electronic appliance parts (moulding).

**Manufacture of paper and paper products**

Formaldehyde is used in the manufacture of paper and paper products. UF resins are used for producing printer paper, kraft paper, packaging paper, hygienic paper, and paper that requires special security features such as for bank notes and passports.

---

Occupational exposure

Formaldehyde can either be inhaled, ingested or absorbed through the skin. Exposure to workers occurs mainly through inhalation of the gaseous form of formaldehyde. In some cases, exposure may occur through dermal contact to the liquid form of formaldehyde. Groups of workers at potential risk include healthcare professionals, medical lab technicians, veterinary and mortuary workers as well as teachers and students who handle biological specimens preserved in formaldehyde or formalin, agricultural workers, workers employed in the sector of wood and wood products where formaldehyde-based resins are used (and, in some cases, produced), and workers of chemical industry where formaldehyde-based products are manufactured. In almost all relevant identified uses of formaldehyde and formaldehyde releasers, worker tasks may result in formaldehyde exposure. These include but are not limited to: transferring operations, mixing or blending processes, surface applications (e.g. roller or brushing application, spraying, dipping and pouring), sampling, laboratory analysis, maintenance and repair operations, cleaning and waste management, and handling of products that may release formaldehyde (e.g. panels, building materials, etc.). The main factors that affect occupational exposures to formaldehyde include the level of automation of the facility, including amount and frequency of manual operations and maintenance activities, the condition of the piping and equipment, the presence and efficiency of fume hoods or local collection systems at the source of the emissions, the efficiency of the general ventilation system, training and appropriate use of PPE.

In 2016, between 990,000 and 2.2 million workers were estimated to be exposed to formaldehyde. An overview table with estimations based on different data sources (CAREX, SUMER, FINJEM and other) is provided on pp. 146-147 of the staff working document for the impact assessment of the third amendment to the CMD (now CMRD).

Health effects

Exposure to formaldehyde can irritate the skin, nose, airways, throat, lungs and eyes. Repeated exposure to formaldehyde can lead to cancer. Exposure to formaldehyde has been linked to rare nose and throat cancers in workers, as well as pointing to a possible link between formaldehyde exposure and cancers of the hematopoietic and lymphatic systems, particularly myeloid leukaemia. Skin-sensitising properties are relevant in the case of dermal exposure.

EU and IARC classification

Formaldehyde is classified as a carcinogen 1B according to the CLP Regulation, is on the list of CMR substances (carcinogens 1A and 1B) that are restricted under certain conditions for use in textile articles and clothing for consumer use, and is classified as category 1 skin sensitiser. According to the harmonised classification and labelling approved by the EU, formaldehyde is toxic if swallowed, is toxic in contact with skin, causes severe skin burns and eye damage, is toxic if inhaled, may cause cancer, is suspected of causing genetic defects and may cause an allergic skin reaction. Additionally, the classification provided by companies to ECHA in REACH registrations identifies that this substance is fatal if inhaled and causes serious eye damage.

The IARC has concluded that there is sufficient evidence of the carcinogenicity of formaldehyde in humans. Formaldehyde causes leukaemia and cancer of the nasopharynx and there is sufficient evidence in experimental animals for the carcinogenicity of formaldehyde. A positive association between formaldehyde exposure and sinonasal cancer has also been observed. Formaldehyde is classified as carcinogenic to humans (Group 1) by the IARC.

---

**Legislation**

Uses of formaldehyde and certain formaldehyde releasers as biocides or in cosmetics are regulated under the Cosmetic Product Regulation (Regulation (EC) No 1223/2009) and Biocidal Product Regulation (Regulation (EU) No 528/2012).

Binding OELs for formaldehyde were last set in 2019 with the third amendment to the CMD (now CMRD). Following the publication of the third revision of the directive, Member States had to transpose it into their national legislation by 11 July 2021 at the latest.

---

14. Lead (and its inorganic compounds)

Inorganic lead is a malleable, blue-grey, heavy metal that occurs naturally in the Earth’s crust. Lead was one of the first metals used by humans and, consequently, the cause of the first recorded occupational disease (lead colic in a 4th century BC metal worker). Lead can be used as a pure metal, combined with another metal to form an alloy, or in the form of a chemical compound.

**Use of lead**

One of the main uses is for automotive lead-acid storage batteries, a type of rechargeable electric battery that uses an almost pure lead alloy. Lead is an essential constituent of several non-ferrous metal alloys like aluminium, copper and zinc alloys. Lead is also used in ceramic glazes and as a stabiliser in plastics. Lead was used extensively as a corrosion inhibitor and pigment in paints but concerns over its toxicity led to the ban of lead paint for residential and public buildings. Prior to the mid-1980s, the organic lead compounds tetramethyl lead and tetraethyl lead were used as an anti-knock additive and octane booster in gasoline, but environmental exposure concerns resulted in the gradual phase-out of leaded gasoline. Organic lead compounds continue to be used in high octane fuel in the aviation industry for piston engine aircraft.

**Lead alloys**

Lead-formed alloys are typically found in ammunition, pipes, cable covering, building material, solder, radiation shielding, collapsible tubes and fishing weights.

Lead metal or lead alloys are used for various end applications in different sectors, such as: the electrical and electronic industry; construction (building and plumbing with lead sheets and tubes, cutting lead sheet, soldering, etc., manufacture of leaded windows using lead rods and solders); vehicle repair (tyre fitting using lead balance weights, soldering of car radiators); and the fishing equipment industry (fitting of fishing nets using lead sinkers).

In the building industry, most of the lead sheet (or strip) is used as flashings or weatherings to prevent water from penetrating, the remainder being used for roofing and cladding. By virtue of its resistance to chemical corrosion, lead sheet is also used for the lining of chemical treatment baths, acid plants and storage vessels. Lead, alloyed with tin, is used in making organ pipes.¹³²

**Foundries**

Lead is used as an alloying element to produce some types of steel, tin alloys, aluminium, brass and bronzes (copper compounds). Lead is added to the alloys to improve castability, finishing and plating characteristics. In the foundry industry, it is used to produce a broad variety of castings mainly made of copper and aluminium alloys. In Europe (mainly in Germany, France, Italy, Poland and Portugal), a large number of non-ferrous-metal foundries process lead-containing copper and aluminium alloys for taps and fittings for water, gas and sanitary installations, sliding materials (bearing bushes and shells), structural material for certain purposes, for example, ship propellers, water turbines and pumps, and electrical conductors, switches and power supply lines.

Commercial lead metal is described as either primary or secondary. Primary lead is produced directly from mined lead ore. The most common lead ore is galena (lead sulphide). Other elements frequently associated with lead include zinc and silver. In fact, lead ores constitute the main sources of silver, contributing substantially towards the world’s total silver output.

Secondary lead is produced from scrap lead products that have been recycled. Much of the secondary lead comes from lead batteries, with the remainder originating from other sources such as lead pipe and sheet. Lead scrap from pipes and sheet is ‘clean’ and can be melted and refined without the need for a smelting stage.

**Batteries and batteries recycling**

By far the largest single application of lead worldwide is in lead-acid batteries. The most common form of lead-acid battery is the so-called SLI battery (starting, lighting and ignition) used in road vehicles.

---

https://publications.iarc.fr/Publications/media/download/2742/4c6e963acidf7ad3b767d0720848796ef7099dd02a.pdf

European Agency for Safety and Health at Work – EU-OSHA
such as cars and trucks. Another form, the traction battery, is used to power vehicles such as golf carts and airport support vehicles. Other uses of lead power include larger stationary batteries for stand-by emergency power storage in hospitals and other critical facilities, and for some electricity utilities to help meet peak power demands and to maintain a stable electricity supply.

With batteries recycling, the lead can only be obtained by breaking the case open. This is commonly done using a battery breaking machine that, in addition to crushing the case, separates out the different components of the battery and collects them in hoppers. Large quantities of lead, both as the metal and as the dioxide, are used in storage batteries. According to figures from 2003, almost 50% of the 1.6 million tonnes of lead produced in Europe each year have been recycled.

**Soldering**

Soldering is a method of joining materials, in which a special metal (solder) is applied in the molten state to wet two solid surfaces and join them on solidification. Solders are classified according to their working temperatures. Soft solders, which have the lowest melting points, are largely lead-tin alloys with or without antimony, while fusible alloys contain various combinations of lead, tin, bismuth, cadmium and other low melting-point metals. Depending on the application, lead-tin solders may contain from a few per cent to more than 60% tin. A substantial proportion of solder is used in electrical or electronic assemblies. The advances made in the electronics industry have required the development of fast and highly automated methods of soldering. The use of lead solder in plumbing has declined with the replacement of lead piping by copper tubing and, more recently, as a result of concerns of potential leaching of lead into water supplies. Similarly, concerns of possible danger to health have restricted the use of lead solders in the canning industry, formerly an important market.

**Shielding**

The metal is very effective as a sound absorber and as a radiation shield around X-ray equipment and nuclear reactors. It is also used to absorb vibration. The high density of lead sheet and its 'limpness' make it a very effective material for reducing the transmission of sound through partitions and doors of comparatively lightweight construction. A particular advantage of the high density of lead is that only relatively thin layers are needed to suppress the transmission of sound.

Lead and its alloys in metallic form, and lead compounds, are used in various forms of radiation shielding. The shielding of containers for radioactive materials is usually metallic lead. Radioactive materials in laboratories and hospitals are usually handled by remote control from a position of safety behind a wall of lead bricks. X-ray machines are normally installed in rooms lined with lead sheet, lead compounds are constituents of the glass used in shielding partitions to permit safe viewing, and lead powder is incorporated into plastic and rubber sheeting materials used for protective clothing.

**Lead compounds**

According to an ECHA 2019 scientific report, lead and compounds can be divided into three groups:

- metallic lead and inorganic lead compounds (30 listed substances);
- organic lead compounds (nine listed substances); and
- various complex substances containing lead used mainly in the production of secondary lead such as lead matte and lead dross (33 listed substances).

In total, 65 inorganic lead compounds are registered under REACH and/or have a harmonised classification. Of these substances, 33 are only used during the manufacture and recycling of lead and its compounds. These substances are all of complex and variable composition and contain constituents other than only lead compounds.

**Use of lead compounds**

Lead and four out of the 32 remaining lead compounds, which are registered according to the REACH Regulation, cover the use of more than 97% in total volume of the inorganic lead compounds at the time of writing. These four lead compounds are lead monoxide, tetralead trioxide sulphate, pentalead tetraoxide sulphate and orange lead (Pb$_3$O$_4$). The market for lead pigments and

---

compounds constitutes the second largest use of lead after lead-acid batteries. The market peaked in the mid-1980s, when over 500,000 tonnes of lead were used in lead pigments and compounds, mainly by the plastics, glass and ceramics industries.

**Manufacture and use of plastics and paints**

As of 2015, products made from virgin PVC resin by European converters no longer contain lead. However, lead may still be contained in waste PVC.

Use of lead stabilisers for PVC has been phased out, but some lead pigments are still used in some plastics. Lead pigments are used for colouring or as anticorrosive in paints and coatings on steel structures, road markings, and in consumer products (e.g. vintage vehicles) for industrial or professional uses. Lead carbonate (PbCO$_3$), lead sulphate (PbSO$_4$), lead chromate (PbCrO$_4$), lead tetroxide (Pb$_3$O$_4$) and other lead compounds have been applied extensively in paints, although in recent years this use has been curtailed to reduce health hazards. Lead chromate (yellow) and lead molybdate (red orange) were used in plastics and to a lesser extent in paints. Lead chromate was used extensively as the yellow pigment in road markings and signs, and lead tetroxide in rust-inhibiting priming paints applied directly to iron and steel.

**Ceramic ware products and enamelling**

Lead was used in a wide range of glaze formulations for items such as tableware (earthenware and china), wall and floor tiles, porcelain and sanitary ware, and electrical transistors and transducers. The lead compounds used were mainly lead monoxide (litharge, PbO), lead tetroxide and lead silicates. Used in appropriate amounts within silicate glazes, lead improves the chemical durability of glazes and colours on ceramic wares, helping them to withstand detergent attack and producing a smooth, durable surface that resists scratching and knife marking.

**Production of lead compounds and lead frits**

Various lead compounds are produced using lead oxides as intermediates. All industrial manufacturing of lead oxides uses ingots of highly refined lead metal (99.9%) as raw material. The process is an oxidation of lead with atmospheric oxygen. Both the oxidation products and the final products are powders.

**Lead oxide** (usually lead monoxide) is used in the production of fine ‘crystal glass’ and ‘flint glass’ with a high index of refraction for achromatic lenses. Lead is also used in optical glass (e.g. telescopes, binoculars), ophthalmic glass (e.g. spectacles), electrical glass (e.g. lamp tubing, cathode ray tubes), and radiation protection glass (e.g. for windows in remote-handling boxes, television tubes). The starting materials for the production of leaded glass are lead oxides (predominantly red lead oxide, but also lead oxide). Lead glass contains typically 18-40% (by weight) lead oxide (PbO), while modern lead crystal, historically also known as flint glass due to the original silica source, contains a minimum of 24% lead oxide. Key countries for lead crystal glass manufacture are Belgium, Czech Republic, France, Germany, Hungary, Ireland, Italy, Poland, Portugal, Slovenia and the UK.

**Lead nitrate and acetate** are soluble salts that serve as intermediates and in specialty applications. Lead salts such as lead arsenate have been used as insecticides, but in recent years this use has been almost eliminated.

**Occupational exposure**

Lead enters the body primarily through inhalation and ingestion. Workers are mainly exposed to lead by breathing in lead-containing dust and fumes at work.

Workers are exposed to lead as a result of the production, use, maintenance, recycling and disposal of lead material and products. Occupational exposure in foundries takes place in a number of processes such as casting, pouring, shake out, grinding or cutting. Additionally, exposure may occur during melting of the lead-containing alloys or during the machining of castings. Many workers may potentially be exposed by working with lead metal, for example, soldering or constructing buildings and industrial installations using lead sheets, profiles and tubes. Lead exposure occurs in most industry sectors, including construction, manufacturing, wholesale trade, transportation, remediation and even recreation. Construction workers are also exposed to lead during the removal, renovation or demolition of structures painted with lead pigments. Workers may also be exposed during installation, maintenance
or demolition of lead pipes and fittings, lead linings in tanks and radiation protection, and leaded glass, in work involving soldering, and other work involving lead metal or lead alloys. In general industry, workers come in contact with lead in solder, plumbing fixtures, rechargeable batteries, lead bullets, leaded glass, brass or bronze objects, and radiators. Lead exposure can occur not only in the production of these kinds of articles but also in their use (e.g. firing ranges), repair (e.g. radiator repair), and recycling (e.g. lead-acid battery recycling). For occupational exposure by production of glass, exposure in the raw material and forming processes is primarily due to lead oxides, whereas in the cutting and polishing processes, some lead exposure may be to related to leaded glass. Occupational exposure by production of ceramic ware with lead-containing glazes takes place in the production of frits (raw material handling, smelting, quenching and wet milling/grinding), the production and handling of pigments (weighing, ball milling and filling), the manual transfer of lithographs, manual painting and artwork, printing and the glazing of ceramics (for instance through dipping and spraying). Occupational exposure due to recycling of PVC may take place in the shredding or micronisation of waste PVC material (grinding), or the compounding and converting process.

Workers at indoor firing (shooting) ranges may be exposed to dangerous levels of lead. Several sources of airborne lead have been identified: fragmentation of lead bullets during firing; the explosive vaporisation of the primer, which can contain both lead stypnate, lead azide and lead peroxide; and inadequate ventilation of the range. Instructors are generally exposed to the highest concentrations of airborne lead due to their regular duties, which include supervising the range, cleaning and test-firing weapons, and preparing training ammunition from commercially purchased components.

Pregnant women or those who might become pregnant must avoid lead exposure because it is toxic to the foetus. Another source of environmental exposure to lead is from workers who take home lead dust on their clothing and shoes.

According to the background study for the amendment to the CMRD from 2021, in total, it was estimated that between 57,200 and 148,500 workers (mid-range 102,900) were exposed to lead at relevant levels in all sectors. An overview on the number of workers in different sectors is provided on p. 205 of the background report for the impact assessment for the fifth amendment of the CMRD.

**Health effects**

Lead passes through the lungs into the blood where it can harm many of the body’s organ systems. While inorganic lead does not readily enter the body through the skin, it can enter the body through accidental ingestion (eating, drinking and smoking) via contaminated hands, clothing and surfaces. Workers may develop a variety of ailments, such as neurological effects, gastrointestinal effects, anaemia and kidney disease. Depending on the level of exposure the symptoms can be less severe: elevated blood pressure, muscle pain, headache, mood disorders, difficulties with concentration, vomiting, loss of appetite and so on.

In occupational studies on lead-exposed workers, exposure assessment is complicated by the historical fact that workers with high exposure often were removed from the job, either temporarily or permanently. This may introduce exposure misclassification, making it difficult to discern dose–response relationships using conventional measures such as cumulative exposure or duration of exposure to lead.

Based on limited evidence of human carcinogenic effects, workers may develop stomach cancer and lung cancer following inhalation exposure to lead, but more studies are needed to demonstrate the cancer risks compared to the levels and durations of lead exposure, and possibly confounding factors such as smoking, diet and other carcinogens in the workplace. Experimental research indicates that rats and mice develop renal tumours following exposure to lead.

---

EU and IARC classification

The IARC in its latest assessment\(^\text{135}\) concluded that:

- there was limited evidence in humans for the carcinogenicity of inorganic lead compounds;
- there was inadequate evidence in humans for the carcinogenicity of organic lead compounds;
- there was sufficient evidence in experimental animals for the carcinogenicity of inorganic lead compounds;
- there was sufficient evidence in experimental animals for the carcinogenicity of lead acetate, lead subacetate, lead chromate and lead phosphate;
- there was inadequate evidence in experimental animals for the carcinogenicity of lead oxide and lead arsenate;
- there was inadequate evidence in experimental animals for the carcinogenicity of organic lead compounds;
- there was inadequate evidence in experimental animals for the carcinogenicity of tetraethyl lead; and
- there was inadequate evidence in experimental animals for the carcinogenicity of lead powder.

Therefore, the IARC concluded that:

- inorganic lead compounds are probably carcinogenic to humans (Group 2A); and
- organic lead compounds are not classifiable as to their carcinogenicity to humans (Group 3).

Most of the inorganic and organic lead compounds have a common harmonised EU classification under the entry "lead compounds with the exception of those specified elsewhere in this Appendix (Index No 082-001-00-6)".

According to the harmonised classification and labelling approved by the EU, lead chromate may cause cancer, may damage the unborn child and is suspected of damaging fertility, and may cause damage to organs through prolonged or repeated exposure.

Lead chromate, lead tetroxide, lead carbonate and lead monoxide are classified as toxic for reproduction.

According to the harmonised classification and labelling approved by the EU, lead acetate may damage the unborn child and is suspected of damaging fertility, is harmful if swallowed, is harmful if inhaled, and may cause damage to organs through prolonged or repeated exposure.

According to the harmonised classification and labelling approved by the EU, lead di(acetate) may damage the unborn child and is suspected of damaging fertility, and may cause damage to organs through prolonged or repeated exposure. Additionally, the classification provided by companies to ECHA in REACH registrations identifies that this substance may damage fertility or the unborn child, is suspected of causing cancer, may cause harm to breast-fed children, is harmful if swallowed, is harmful if inhaled and causes serious eye damage.

Legislation

Lead is included in the Candidate List of SVHCs for authorisation for being toxic to reproduction.

In April 2023, ECHA recommended adding lead to the Authorisation List (REACH Annex XIV) based on a prioritisation supported by the opinion of the Member State Committee.\(^\text{136}\) In the next step, the European Commission and the Member States will discuss the recommendation in relation to other ongoing regulatory activities for lead to ensure that adequate and efficient risk management measures are in place. If the European Commission decides to include lead in the Authorisation List, after a given date, its use and placing on the market will be prohibited unless the company receives an authorisation.


\(^{136}\) Recommendation of the European Chemicals Agency of 12 April 2023 for the inclusion of substances in Annex XIV to REACH (List of Substances subject to Authorisation): https://echa.europa.eu/documents/10162/ec9a9309-c24-c555-4364-1198ab02c1d1
Some of the uses in the scope of the authorisation are batteries, ammunition, cables, vehicles, machinery, electronics, radiation shielding, sanitary, construction, art and musical instruments. In addition, lead carbonate and sulphates are not allowed to be used or placed on the market in paint, except for the restoration and maintenance of works of art and historic buildings and their interiors.

Since February 2023, the use of lead gunshot in wetlands has been prohibited across the EU/European Economic Area. In 2021, ECHA proposed an additional restriction on the use of lead in outdoor shooting and fishing. This proposal is currently in the European Commission for decision-making.

The EU’s RoHS Directive\textsuperscript{137} restricts lead in all electrical and electronic products with very limited exceptions specified in the directive. The limit is 0.1%.

The three lead pigments (lead chromate, lead sulphochromate and lead molybdate chromate, colour range from yellow to orange to red) are subject to authorisation. Lead chromate has been defined as an SVHC and included in the Candidate List of SVHCs for authorisation as well as included in Annex XIV of REACH as an SVHC requiring authorisation before it is used. Some uses are restricted under Annex XVII of REACH.\textsuperscript{138}

**Lead tetroxide** (orange lead) has been defined as an SVHC and included in the Candidate List for authorisation. Some uses are restricted under Annex XVII of REACH.\textsuperscript{139} Some uses of **lead carbonate** (white lead) are restricted under Annex XVII of REACH.\textsuperscript{140}

**Lead monoxide** is an SVHC and included in the Candidate List for authorisation. Some uses are restricted under Annex XVII of REACH,\textsuperscript{141} as well as are some uses of lead silicate.\textsuperscript{142}

Some uses of lead acetate are restricted under Annex XVII of REACH.\textsuperscript{143}

Lead di(acetate) is also an SVHC and included in the Candidate List for authorisation. Some uses are restricted under Annex XVII of REACH.

The use of lead solders has been effectively banned in Europe for most purposes since 1 July 2006 by the EU Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (2002/95/EC), commonly referred to as the Restriction of Hazardous Substances Directive, or RoHS. The reason for this change was to reduce the discharge of lead into the environment, particularly during the disposal of electronic components. However, there are still some applications where lead-based solders are permitted. The RoHS Directive\textsuperscript{144} restricts lead and its compounds in all electrical and electronic products. The limit is 0.1%.

From 29 November 2024, companies are prohibited from using lead in PVC articles in the European Economic Area (provided that the concentration level is equal to or greater than 0.1%). On 8 May 2023, the European Commission announced in the official journal to amend Annex XVII to the REACH Regulation to restrict the placing on the market or use of lead and its compounds in polymers or copolymers of vinyl chloride (PVC). The amendment entered into force on 28 May 2023.

Inorganic lead and its compounds have a binding biological limit value and OEL according to the fourth amendment to the CMD (now CMRD).\textsuperscript{145} Biological monitoring must include measuring the blood-lead

\textsuperscript{137} Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) Directive. The RoHS Directive currently restricts the use of ten substances: lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), bis(2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP) and diisobutyl phthalate (DIBP).\textsuperscript{138}

\textsuperscript{138} ECHA substance infocard - lead chromate: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.028.951

\textsuperscript{139} ECHA substance infocard - lead tetroxide: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.013.851

\textsuperscript{140} ECHA substance infocard - lead carbonate: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.009.041

\textsuperscript{141} ECHA substance infocard - lead monoxide: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.013.880

\textsuperscript{142} ECHA substance infocard - lead silicate: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.040.976

\textsuperscript{143} ECHA substance infocard - lead acetate: https://echa.europa.eu/es/substance-information/-/substanceinfo/100.035.784

\textsuperscript{144} Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) Directive. The RoHS Directive currently restricts the use of ten substances: lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), bis(2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP) and diisobutyl phthalate (DIBP).\textsuperscript{145}

level (PbB) using absorption spectrometry or a method giving equivalent results. Medical surveillance has to be carried out if exposure to a concentration of lead in air is exceeded or a blood-lead level exceeding a certain value is measured in individual workers. These limit values have just been introduced. However, they are under revision and a revised text agreed by the co-legislators has been published by the Commission. The co-legislators also agreed on a transitional period for the new biological limit value for lead (until 31 December 2028). Specific provisions on protecting the health of workers who already have high levels of lead in their blood as a result of historical exposure, while ensuring their continuity on the labour market, are planned, as well as guidelines on health surveillance, which should include advice on how to implement provisions relating to blood-lead levels.

15. **Mineral oils (as mists)**

Mineral oils (also known as base oils, mineral base oils or lubricant base oils) are chemical substances prepared from naturally occurring crude petroleum oil. Crude oil is distilled first at atmospheric pressure and then under high vacuum to yield vacuum distillates and residual fractions that can be further refined to mineral oils. Mineral oils refined from petroleum crude oils are complex and variable mixtures of straight and branched-chain paraffinic, naphthenic (cycloparaffinic) and aromatic hydrocarbons having carbon numbers of 15 or more and boiling points in the range of 300-600°C. The hydrocarbon composition and physical characteristics of a mineral oil depend on both the composition of the original crude oil and the processes used during refining (e.g. solvent extraction, hydro-treatment). Production processes of mineral oils have changed substantially over time. In the past, many mineral oils were only mildly refined and contained significant levels of PAHs.

**Use of mineral oils**

A wide variety of mineral oil-containing products including lubricants as well as products intended for non-lubricant purposes are manufactured for different applications. Lubricant products include engine oils, transmission fluids, gear oils and hydraulic fluids, as well as metalworking fluids (also known as metal-removal fluids). Metalworking fluids may be different from other mineral oil-containing products due to the types of additives used, the additive treatment rates, and contaminants — including those of microbial origin — that are associated with use. ‘Non-lubricant’ products include agricultural spray oils, printing inks, tyre oils and so on.

**Mineral oils as used engine oils**

Oils that have been used before in internal combustion engines to lubricate and cool the moving parts within the engine (‘mineral oils as used engine oils’) consist of blends of hydrocarbons including paraffins, naphthenics, and complex/alkylated polyaromatics and lubricating additives. Engine oils are used in internal combustion engines, which power cars, motorcycles, diesel trains, ships, lawn mowers and other machinery.

Occupational exposure is via the dermal route — skin contact during changing of oil or working with engine parts. Recycling of non-metal scrap is another source of exposure, although relatively less important. Inhalation exposure to mineral oils as used engine oils is unlikely. The composition of engine oils, and hence of mineral oils as used engine oils, has been changing over time to meet the requirements of newer engine designs and performance requirements. The composition of engine oils also varies depending on the needs of different engines and operating conditions, and changes during use with the accumulation of fuel components, water, metals, metal oxides and combustion products (including PAHs) within the oil.

Exposure to mineral oils as used engine oils potentially were assessed to concern 1 million workers in Europe, employed mostly in maintenance and repair of motor vehicles (0.9 million). Other sectors included sales, maintenance and repair of motorcycles (fewer than 0.1 million), and recycling of non-metal waste and scrap (fewer than 0.1 million). Around 370,000 companies were estimated to be working in these sectors and a majority of these companies are SMEs. Page 111 of the staff working document accompanying the second amendment of the CMD (now CMRD) provides an overview of the estimated number of workers exposed in the different Member States, based on the IOM study of 2010.\(^{147, 148}\)

---

\(^{147}\) An impact assessment of possible amendments of the directive, covering among other things the inclusion of certain process-generated substances in Annex I to the directive and the revision of existing and the introduction of new OELs for a number of chemical agents in Annex III to the directive: IOM Research Project P937/99, May 2011 ‘Health, social-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure to carcinogens and mutagens at work’. [https://ec.europa.eu/social/BlobServlet?docId=10149](https://ec.europa.eu/social/BlobServlet?docId=10149)

**Occupational exposure**

Mineral oils comprise a diverse set of agents used for a wide range of industrial operations. Oil mists or aerosols can arise from the use of mineral oil both as lubricant and as non-lubricant. In practice, oil aerosols may be generated by several mechanisms such as aeration, contact with a fast-moving surface or by heating. Important applications with potential generation of oil aerosols are metalworking, textile machinery, rock drills, aerosol lubrication, agriculture sprays, concrete mould release agents, the use of corrosion preventatives, printing inks, rubber extenders or lubricant-blending in open processes, and applications in food and pharmaceutical preparations. The particle size of the mists, aerosols or fogs is likely to differ for each of these processes.

There are several occupational environments in which an oil mist can be generated. In these situations, the opportunities for dermal exposure or inhalation exposure, with associated ingestion, are substantial. Such occupations include metalworking, printing press operating, and cotton and jute spinning. A small number of studies have evaluated respiratory morbidity from exposure to mineral oil mist among newspaper pressmen, marine engineers, cable oilers and tunnel blasters.\(^{149}\)

**Health effects**

Exposure to mineral oils as used engine oils may cause skin cancer. The staff working document specified that oils that have been used before in internal combustion engines to lubricate and cool the moving parts within the engine (hereinafter ‘mineral oils as used engine oils’) are among the top 10 carcinogenic substances to which the largest numbers of workers are currently exposed.\(^ {150}\)

In the Opinion of SCOEL, ‘mineral oils as used engine oils’ defined to mean ‘oils that have been used before in internal combustion engines to lubricate and cool the moving parts within the engine’ were carcinogenic in SCOEL Group A, for which no health-based exposure threshold can be derived. SCOEL strongly recommended a skin notation.\(^{151}\)

**EU and IARC classification**

There is evidence that mineral oils vary in their potential to cause cancer with the degree of treatment or processing. Hydro-treatment and solvent extraction reduce the PAH content, and thus the carcinogenicity of the oils. Untreated and mildly treated oils have been classified as Group 1 carcinogens, with sufficient evidence from studies in humans that mineral oils (containing various additives and impurities) that have been used in occupations such as mule spinning, metal machining and jute processing are carcinogenic to humans. A major challenge in making an overall assessment of the carcinogenicity of mineral oils is this diversity in processing, with incomplete information on the extent of processing in specific industrial applications. Mineral oils are typically used as part of a complex mixture for such applications as metalworking, lubrication and cooling. The additional processing and combining with other agents make attribution of risk specifically to mineral oils difficult.

The latest evaluation by the IARC, from 2012 (see above-references study), concluded that:

- There was sufficient evidence in humans for the carcinogenicity of untreated or mildly treated mineral oils. Untreated or mildly treated mineral oils cause cancer of the skin (observed in the scrotum).
- There was sufficient evidence in experimental animals for the carcinogenicity of untreated vacuum distillates, acid-treated oils and aromatic oils, including extracts from solvent treatment of distillates and the high-boiling fraction of catalytically cracked oils (classes 1, 2 and 6).
- There was sufficient evidence in experimental animals for the carcinogenicity of mildly hydrotreated oils (class 4).
- There was sufficient evidence in experimental animals for the carcinogenicity of used gasoline engine oil (class 7.2).

---


\(^{151}\) SCOEL/OPIN/2016-405 mineral oils as used engine oils. Opinion from the Scientific Committee on Occupational Exposure Limits, 2016: https://op.europa.eu/en/publication-detail/-/publication/75c82daa-c682-11e6-a6db-01aa75ed71a1
The criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

- There was weak evidence on the mechanism underlying the effects in humans of exposures to mineral oils. This evidence is based on genotoxic (mutagenic) activity of mineral oils in bacteria and a single cytogenetic study of glassworkers exposed to aerosols of mineral oils.
- Untreated and mildly treated mineral oils are carcinogenic to humans (Group 1).

Legislation

‘Work involving dermal exposure to mineral oils that have been used before in internal combustion engines to lubricate and cool the moving parts within the engine’ has been added to the carcinogenic substances, mixtures and processes listed in Annex I of the CMD (now CMRD) with the second amendment (Directive 2019/130) and a skin notation was assigned to it in Annex III to Directive 2004/37/EC indicating the possibility of significant uptake through the skin. It was considered that there is sufficient evidence of the carcinogenicity of mineral oils that have been used before in internal combustion engines to lubricate and cool the moving parts within the engine. Those used mineral engine oils are process-generated and therefore they are not subject to classification in accordance with Regulation (EC) No 1272/2008 of the European Parliament and of the Council. SCOEL had identified the possibility of significant uptake through the skin for those oils, concluded that occupational exposure occurs through the dermal route and strongly recommended the establishment of a skin notation.

---

16. Nickel (and compounds)

Nickel is a hard, silvery-white metal. The chemical properties of nickel (i.e. hardness, high melting point, ductility, malleability, somewhat ferromagnetic, fair conductor of heat and electricity) make it suitable to be combined with other elements to form many alloys.

**Use of nickel**

Before nickel in any form is put to use, it first has to be explored/mined, refined, fabricated and integrated into products for domestic use and for export. In the EU, nickel ore is mined on a large scale in Greece and in an increasing scale in Finland. In Greece, there is no refining activity but there is smelting. In Finland, the mining is accompanied by a refinery. According to ECHA, the EU uses approximately 700,000 tonnes of nickel per year: 387,200 tonnes in 2008 from mines, the rest recovered from recycled material, mainly stainless steel. Although the majority of nickel-containing scrap is recycled, the demand for nickel-containing materials is increasing around the world, and as a result there is not enough scrap to satisfy demand. Most nickel-containing products have long lives. The average life of nickel-containing products is in the range of 25-35 years and for some applications such as roofs and cladding this can go up to 100 years.

Nickel is very widely distributed in mining, in the heavy industries (milling, foundries, refining) and in the manufacturing industries (production of stainless steel and steel alloys, production of nickel alloys, hot cutting and welding, nickel plating, chemical production and mixing, manufacture of catalysts, manufacture of Ni-Cd batteries, manufacture of coins, jewellery, pigments and powders). It imparts such desirable properties as corrosion resistance, heat resistance, hardness and strength.

**Manufacture of alloys**

Pure nickel metal is used to prepare nickel alloys (including steels). About 90% of all new nickel sold each year in the EU goes into alloys, two-thirds of that going into the production of over 8 million tonnes of stainless steel (containing 8-12% nickel). This accounts for about 35% of all the stainless steel produced in the world. It is used as such for plating, electroforming, coinage, electrical components, tanks, catalysts, battery plates, sintered components, magnets and welding rods. Stainless steels are used in general engineering equipment, chemical equipment, domestic applications, hospital equipment, food processing, architectural panels and fasteners, pollution-control equipment, cryogenic uses, automotive parts and engine components.

Nickel-containing steels with low nickel content (< 5%) are used in construction and tool fabrication. Nickel is also used in alloys similar to stainless steel, but with a higher nickel content, in the chemical, petrochemical, energy and aerospace industries. Alloys of iron and nickel find many uses in electrical and electronics industries and other specialist engineering fields. Alloys of copper and nickel are used in coinage and marine engineering. There are about 3,000 nickel-containing alloys in everyday use.

**Slags, ferronickel manufacturing**

Ferronickel production plants generate slag as a by-product from smelting and refining of iron-containing nickel ores. The slag is used in many applications, for civil engineering construction (embankments, ballasts, granular bases and bricks), in high-density aggregate, as abrasives in sandblasting (and possibly in electroplated abrasive tools). The slag can be recovered from various stages in the smelting process as electric furnace air-cooled slag, electric furnace water-cooled slag and air-cooled converter slag. The nickel/iron alloy is generally produced as granules or ingots.

**Hard-wearing coatings – plating or electroforming**

Nickel provides hard-wearing coatings for either decorative (‘brushed nickel’ and ‘chrome’ finishes) or engineering purposes using surface technologies such as plating and electroforming. Surface treatment or finishing operations can be carried out using manual, mechanised or fully automated processes. For plating processes, workpieces are dipped in the nickel-containing solution and other cleaning, strike and passivating process solutions held in tanks arranged sequentially in a ‘plating line’. Rinse tanks are situated between each processing tank, with workpieces being dipped in these to wash off the processing solutions before the workpieces enter a different tank solution to avoid contamination.
**Nickel compounds**

According to an ECHA evaluation, there were 59 nickel-containing substances for which a harmonised classification is available, of which 17 are registered, and another 36 substances that have been self-classified and for which a registration is available. The inorganic compounds (35 substances) can be grouped according to their solubility in water: soluble compounds include nickel chloride, nickel sulphate and nickel nitrate, and less-soluble compounds include nickel oxide and nickel subsulphide. Solubility may be important with regard to all relevant routes of exposure.

Nickel salts are used in electroplating, ceramics, pigments, and as intermediates (e.g. catalysts, formation of other nickel compounds).

**Nickel monoxide** is used to colour glass greyish-brown, yellow, green, blue to violet, depending on the glass matrix. Metallic nickel is used in the offline coating of float glass. Layer thicknesses of a few nanometres are produced on the glass surface. These consist of process-related mixtures of metallic nickel and nickel oxides. The container glass industry uses metallic moulds to shape molten glass into bottles or jars with the help of compressed air. These moulds are repaired with metallic nickel (welding and polishing) and there could be a chemical transformation of metallic nickel into nickel compounds at this stage, but exposure is likely to be primarily to metallic nickel. Nickel compounds may be generated during welding. Nickel oxide is also used as an essential constituent to produce certain crystal glass substances needing specific colouring/decolouring treatment to induce high brilliance. In some niche applications of the container glass industry (called ‘flaconnage’, approximately 1% of the total container glass production reaching 21 million tonnes per year), companies use frits substances with nickel oxide. The nickel frits are used to produce coloured glass and in particular coloured perfumery bottles. Nickel compounds are only used for optical glasses in small quantities. One plant is using less than 700 kg of nickel carbonate per year. Another plant is using less than 300 kg nickel oxide every few years for one campaign. Both **nickel oxide** and **nickel carbonate** are used as colorants for certain filter glasses.

**Sinter nickel oxide** is used in nickel catalysts in the ceramics industry, in the manufacture of alloy steel and stainless steel, in the manufacture of nickel salts for specialty ceramics, and in the manufacture of Ni-Cd batteries and Ni-MH batteries.

**Nickel hydroxide** is used as a catalyst intermediate, and in the manufacture of Ni-Cd batteries.

**Nickel sulphide** is used as a catalyst in petrochemical hydrogenation when high concentrations of sulphur are present in the distillates or as an intermediate in the metallurgical industry.

**Nickel acetate** is used in electroplating, as an intermediate (e.g. as catalysts and in the formation of other nickel compounds), as a dye mordant and as a sealer for anodised aluminium.

**Nickel carbonate** is used in the manufacture of nickel catalysts, pigments, and other nickel compounds (e.g. nickel oxide, nickel powder); in the preparation of coloured glass; and as a neutralising compound in nickel-electroplating solutions. Nickel ammonium sulphate is used as a dye mordant, in metal-finishing compositions and as an electrolyte for electroplating.

**Nickel chloride** is used as an intermediate in the manufacture of nickel catalysts, and to absorb ammonia in industrial gas masks.

**Nickel nitrate hexahydrate** is used as an intermediate in the manufacture of nickel catalysts and Ni-Cd batteries.

**Nickel sulphate hexahydrate** is used in nickel electroplating and nickel electrefining, in 'electroless' nickel plating, and as an intermediate (in the manufacture of other nickel chemicals and catalysts).

**Manufacture of batteries**

Battery electrodes that use nickel substances are composite electrode structures where an ‘active mass’, containing nickel and other conductive materials, is supported by or encased in ‘current collector’ plates that are coated with nickel. Nickel metal, nickel sulphate (probably with nickel chloride when electroplating from a Watts nickel bath) and nickel dihydroxide are used widely in the battery industry to make four types of electrodes. Nickel dinitrate and nickel metal are used to make one type of electrode.
Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

Catalysts

Nickel-containing catalysts for use at industrial sites are generally in the form of a nickel sulphide (NiS, or nickel subsulphide, N\textsubscript{2}S\textsubscript{2}, or a mixture of both), nickel oxide or nickel metal. Nickel has strong catalytic properties that serve the chemical and petrochemical industries. Nickel-containing catalysts are generally supported and produced in shaped (tablets, pellets, droplets, etc.) or powdered forms. These are dependent on small powder and chemical production facilities found in most EU countries with the large-scale production taking place in Denmark, France, the Netherlands, Finland, and Sweden.

Use as intermediate

Under the REACH Regulation, an intermediate is a substance that is manufactured for and consumed in or used for chemical processing in order to be transformed into another substance (REACH Article 3(15)). This can cover a wide variety of nickel compounds that are often used in the formation of other nickel compounds (and nickel). The main use as intermediate is in the manufacturing of catalysts.

Examples of intermediate uses are:

- nickel hydroxide, nickel chloride, green nickel oxide and nickel nitrate hexahydrate used to manufacture catalysts;
- nickel acetate, black nickel oxide and nickel sulphate hexahydrate used to manufacture catalysts and other nickel compounds; and
- nickel carbonate used in the manufacture of nickel catalysts, pigments, and other nickel compounds (including nickel oxide, nickel powder).

Pigments

Metallic pigments provide an essential tool in the hands of the formulators and manufacturers of organic-based coatings. The inherent visual properties of the various types of metallic pigments generally determine the applications in which they are used. Nickel pigments exhibit good corrosion resistance, attractive visual appearance, high electrical conductivity and ferromagnetism.

Nickel pigments can be used in three kinds of coatings:

- decorative/functional coatings: decorative grades of nickel flakes are used to produce bright, fully metallic coatings, stable in aqueous media and corrosion resistant;
- electrically conducive coatings: to provide shielding for all types of electronics equipment in order to avoid radiofrequency and electromagnetic interference problems; and
- nickel-containing coatings for magnetic applications: as nickel is the only substance that is both strongly ferromagnetic at ambient temperatures and available in small particles suitable for use as pigments.

Some other examples of nickel compounds that are used as pigments include nickel carbonate and nickel titanate.

Occupational exposure

Nickel species relevant for occupational exposure include metallic nickel, poorly soluble nickel species such as oxides and sulphides as well as water-soluble nickel salts.

Nickel, in the form of various alloys and compounds, has been in widespread commercial use for over 100 years. Several million workers worldwide are exposed to airborne fumes, dusts and mists containing nickel and its compounds. Exposures by inhalation, ingestion or skin contact occur in nickel-producing industries (e.g. mining, milling, smelting and refining), as well as in nickel-using industries and operations (e.g. alloy and stainless steel manufacture; electroplating and electrowinning; welding, grinding and cutting).

The Nickel Institute has identified a wide range of occupations with direct exposure to nickel:¹⁵⁴

- refining, main part of the refining processes;

Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

- last-stage refining, handling of primary nickel;
- alloy production, melting and foundry techniques;
- alloy production, powder metallurgy;
- batteries, nickel metal or unknown type of nickel species as feedstock;
- nickel catalysts, nickel metal or unknown type of nickel species as feedstock;
- nickel in the production of chemicals;
- contact with coins;
- contact with tools and other nickel-releasing surfaces;
- use of batteries; and
- use of catalysts.

The first two sectors correspond to the nickel-producing industry, while the rest belong to the nickel-using industry.

Metal fumes are formed by evaporation, condensation and oxidation of metals in air. Furnace tenders, melters, ladle-men, pourers and crane drivers are exposed to fumes from molten metal. Fettlers (finishers) are exposed to metal fumes and dusts from grinding, welding and flame-cutting operations.

Workers in electroplating shops may be exposed to nickel substances in the form of mists, dusts or powders from electrolytic solutions, nickel anodes, nickel plate or wastes during the plating operation, maintenance of solutions and plant or cleaning of the premises, equipment and plant. These present an inhalation risk. Skin contact with nickel plating solutions can occur, for example, when loading and unloading workpieces from the jigs and barrels and making up, replenishing or destroying plating solutions. Adding nickel powders/solutions to plating baths may result in spills or generate dusts or mists.

Maintenance and repair and cleaning work done to tanks and pumps also present such dermal (and inhalation) exposure risks. Polishing the plated nickel workpiece on a vibratory or pedestal system can generate nickel dust.

**Welding**

Welding generates fumes that are essentially a mixture of metallic oxides (including nickel), fluorides and silicates. Therefore welding has the potential to expose workers to welding fumes containing nickel.

There are many types of welding and all the conventional welding processes can be used to weld nickel and its alloys, and matching welding consumables are available. The one to be used depends upon the metal substrates, the application and a variety of other variables.

Insoluble nickel is the predominant exposure in nickel-producing industries, whereas soluble nickel is the predominant exposure in the nickel-using industries. Based on occupational exposure to known and suspected carcinogens collected during the period 1990-1993, the CAREX database estimated that 547,396 workers were exposed to nickel and nickel compounds in the EU.155

In the impact assessment of the fourth amendment to the CMD (now CMRD), 87,500 workers were estimated to be exposed in the sectors considered in this impact assessment, namely oil refineries, pigments, frits, catalysts, glass, metals and alloys, metal surface treatment, batteries, materials recovery and welding. Other sectors were not considered (e.g. agriculture, mining)156 because of a lack of data or exposures being regarded as marginal.

The primary route of exposure is by dermal contact or by inhalation of aerosols, dusts, fumes or mists containing nickel. Dermal contact may also occur with nickel solutions.

---

155 See: [https://www.carexcanada.ca/profile/nickel-occupational-exposures/](https://www.carexcanada.ca/profile/nickel-occupational-exposures/)
**Health effects**

Occupational exposure results in elevated levels of nickel in blood, urine and body tissues, with inhalation as the main route of uptake. The penetration in the organism, the absorption and the elimination of nickel and its compounds depend on their physical state and largely on the route of exposure. In humans, nickel ions can be taken up via the skin, via the gastrointestinal tract or by inhalation.

Carcinogenic effects of nickel have long been recognised. Exposure to nickel compounds is associated with an increased cancer risk in the lungs and nasal cavity, as well as with inflammatory responses/fibrosis in the lungs. Since mechanistic data indicate an indirect genotoxic mode of action, nickel is considered a carcinogen with a practical threshold.

The carcinogenicity of nickel compounds has been clearly demonstrated in epidemiological studies. Within the different cohorts attempts have been made to rank the carcinogenic potentials for the different nickel species, water-soluble nickel, particulate nickel compounds and metallic nickel. Both water-soluble and poorly water-soluble, particulate nickel compounds are to be considered as carcinogenic in humans, whereas epidemiological studies on metallic nickel do not indicate a carcinogenic potential. It has to be emphasised, however, that epidemiological data alone are not considered sufficient to exclude any nickel species such as metallic nickel from further considerations, since there are no cohorts that have been exclusively exposed to one nickel species.

The reproductive system is also regarded as a potential target for the inorganic compounds of nickel, both in animal experiments and in humans. Nickel compounds show reproductive toxicity, including effects on fertility and development in animal studies.157

Nickel and nickel compounds can cause contact dermatitis and contact urticaria. Nickel is the most commonly diagnosed cause of allergic contact dermatitis worldwide, mostly through non-occupational exposure. However, occupational exposure to nickel salts in a work situation (for instance in the electroplating industry) may cause contact sensitisation. In contrast, cases of occupational asthma by exposure to nickel are rare and co-exposure, for example, to chromium, cobalt or hard metals, usually occurred, indicating that nickel is not a significant respiratory sensitiser.

Working with nickel (e.g. in nickel refining or welding) can cause chronic bronchitis and decreased lung function, as well as immunological and renal effects. It is not clear if these effects are due entirely to nickel since exposure to other substances (e.g. cobalt) also occurs in these settings.

Exposure to nickel nanoparticles has also been considered as a potential health issue.158,159,160

**EU and IARC classification**

Annex VI of the CLP Regulation lists 54 entries for the classification of nickel and its compounds. Nickel metal (and nickel powder) are classified as suspected human carcinogens (carcinogen 2),161 as is nickel tetracabonyl; all other nickel compounds are classified as known human carcinogens (carcinogen 1A). Nickel and all its compounds, except for nickel tetracabonyl, are classified as skin sensitisers, and of these compounds 31 are classified as respiratory sensitisers. Twenty-seven compounds are classified as reprotoxic (25 as reprotoxic 1B and two as reprotoxic 1A) and 27 compounds are classified as suspected mutagens (Mutagen category 2).162

---


According to the EU harmonised classification, nickel oxide, nickel hydroxide, nickel sulphide, nickel acetate and nickel carbonate have a harmonised classification as carcinogen 1A. Nickel nitrate hexahydrate has no harmonised classification, but was classified by most registrants as carcinogen 1A, while nickel dinitrate has a harmonised classification as carcinogen 1A. Nickel sulphate has a harmonised classification as carcinogen 1A.

Based on evidence of increased respiratory cancer risk of cohorts of workers from different countries engaged in refining and processing of sulphidic nickel ores, nickel compounds have been classified by the IARC as Group 1 carcinogens.

In its evaluation from 2012, the IARC concluded that:

- There was sufficient evidence in humans for the carcinogenicity of mixtures that include nickel compounds and nickel metal. These agents cause cancers of the lung and of the nasal cavity and paranasal sinuses.
- There was sufficient evidence in experimental animals for the carcinogenicity of nickel monoxides, nickel hydroxides, nickel sulphides (including nickel subsulphide), nickel acetate and nickel metal.
- There was limited evidence in experimental animals for the carcinogenicity of nickelocene, nickel carbonyl, nickel sulphate, nickel chloride, nickel arsenides, nickel antimonide, nickel selenides, nickel sulpharsenide and nickel telluride.
- There was inadequate evidence in experimental animals for the carcinogenicity of nickel titanate, nickel trioxide and amorphous nickel sulphide.
- In view of the overall findings in animals, there was sufficient evidence in experimental animals for the carcinogenicity of nickel compounds and nickel metal.

Nickel compounds were therefore classified as carcinogenic to humans (Group 1).

Nickel metal was classified as Group 2B.

While the carcinogenic properties of nickel compounds are widely accepted, several attempts have been undertaken to elucidate the relative contributions of diverse nickel species, that is, metallic nickel, poorly water-soluble nickel sulphide or nickel oxide and water-soluble nickel salts.

**Legislation**

Nickel and its compounds have been assessed by SCOEL in 2011 and by ECHA in 2018.

---

168 ECHA substance infocard - nitric acid, nickel(2+) salt, hexahydrate: https://echa.europa.eu/substance-information/-/substanceinfo/100.108.590
A binding OEL for respirable and inhalable dust containing nickel has been included in the CMRD with the fourth amendment to the CMD, with a transitional phase until 18 January 2025.  

Seventy-two nickel compounds are registered under REACH. Nickel compounds are not subject to authorisation according to Annex XIV of REACH. However, as indicated in Annex XVII of REACH (entry 27), the use of nickel and its compounds in jewellery (including watches) and articles that come into contact with the skin is restricted. In addition, all the nickel compounds and their mixtures cannot be supplied to the general public due to the restriction entry 28 of Annex XVII of REACH.

---

17. **o-Toluidine**

o-Toluidine (o-toluidine) is a colourless liquid, a high-production-volume chemical used in the manufacture of rubber chemicals, herbicide intermediates, dye intermediates and some drugs like the local anaesthetic prilocaine.

**Use of o-toluidine**

o-Toluidine is used as an intermediate in the synthesis of the large-volume herbicides, metolachlor and acetochlor, in the manufacture of more than 90 dyes and pigments (e.g. acid-fast dyestuffs, azo pigment dyes, triarylmethane dyes, sulphur dyes and indigo compounds), and as an intermediate for synthetic rubber and rubber-vulcanising chemicals, pharmaceuticals, pesticides and other chemicals. o-Toluidine is also used in the clinical laboratory as an ingredient in a reagent for glucose analysis, and for tissue staining.

**Occupational exposure**

In the chemical industry exposure to o-toluidine can occur during its production and during its use in the production of herbicides, dyes and pigments, rubber chemicals, epoxy resin hardeners, fungicide intermediates and pharmaceutical intermediates.

Occupational exposure to o-toluidine can occur by inhalation or skin contact during its production, or during the production of dyes, pigments and rubber chemicals manufactured from this chemical. Laboratory and medical personnel may be exposed when using o-toluidine for staining tissues. The industries in Europe that report the highest workers' exposure levels are: i) manufacturing of chemicals, chemical products and man-made fibres; and ii) manufacture of rubber products. Medical and laboratory personnel are also potentially exposed to o-toluidine, although air concentrations are reportedly low.

In the EU there were approximately 5,500 workers estimated to be potentially exposed to o-toluidine, but this is likely an underestimation. The available data indicated that the EU o-toluidine production was centred in France, Germany, Italy, the Netherlands and the UK. The available information suggested that there was no o-toluidine production in the rest of Europe.

**Health effects**

o-Toluidine may cause bladder cancer. Occupational exposure is most likely to occur through inhalation and dermal contact.

**EU and IARC classification**

According to the harmonised classification and labelling approved by the EU, o-toluidine is toxic if swallowed, is toxic if inhaled, may cause cancer, is very toxic to aquatic life and causes serious eye irritation.

o-Toluidine meets the criteria for classification as carcinogenic (category 1B) in accordance with Regulation (EC) No 1272/2008 and is therefore a carcinogen within the meaning of Directive 2004/37/EC.

o-Toluidine has been classified by the IARC as carcinogenic to humans (Group 1).

---


Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

Legislation

o-Toluidine has been added to the REACH Candidate List of SVHCs potentially to be made subject to authorisation.

Binding OELs values for o-toluidine were set in 2017 with the first amendment to the CMD (now CMRD) and it was assigned a notation indicating the possibility of significant uptake through the skin.179 Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with this directive by 17 January 2020.

18. Respirable crystalline silica

Crystalline silica is a common mineral found in the Earth’s crust. The various forms of crystalline silica are α-quartz, β-quartz, α-tridymite, β-tridymite, α-cristobalite, β-cristobalite, keatite, coesite, stishovite and moganite. The most abundant form of silica is α-quartz, and the term quartz is often used in place of the general term crystalline silica.

Use of silica

Most silica in commercial use is obtained from naturally occurring sources. The three predominant commercial silica product categories are: sand and gravel, quartz crystals and diatomites. It is also used to make products such as glass, pottery, ceramics, bricks and artificial stone.

Sand and gravel

Although silica sand has been used for many different purposes throughout history, its most ancient and principal use has been in the manufacture of glass (e.g. containers, flat plate and window, and fibreglass). Sands are used in ceramics (e.g. pottery, brick and tile), foundry (e.g. moulding and core, refractory), abrasive processes (e.g. blasting, scouring cleansers, sawing and sanding), hydraulic fracturing applications and many other uses. Several uses require the material to be ground (e.g. scouring cleansers, some types of fibreglass, certain foundry applications). In some uses (e.g. sandblasting, abrasives), grinding also occurs during use.

Quartz

Quartz has been used for several thousand years in jewellery as a gemstone (e.g. amethyst, citrine), and is used extensively in both the electronics and optical components industries. Electronic-grade quartz is used in electronic circuits, and optical-grade quartz is used in windows and other specialised devices (e.g. lasers).

Diatomites

Diatomites are used in filtration, as fillers (in paint, paper, synthetic rubber goods, laboratory absorbents, anti-caking agents and scouring powders), and as carriers for pesticides. They impart abrasiveness to polishes, flow and colour qualities to paints, and reinforcement to paper. Other uses include insulators, absorption agents, scourer in polishes and cleaners, catalyst supports and packing material.

Process-generated or natural exposure

Materials like sand, stone, concrete and mortar contain crystalline silica. Respirable crystalline silica (RCS) is created when cutting, sawing, grinding, drilling and crushing stone, rock, concrete, brick, block and mortar, so it is also a process-generated substance. The most commonly occurring polymorphs are quartz, cristobalite and tridymite, which are found in rocks and soil. These forms of silica can be released to the environment via both natural and anthropogenic sources (e.g. foundry processes, brick and ceramics manufacturing, silicon carbide production, burning of agricultural waste or products, and calcining of diatomaceous earth). Farmers may be exposed to silica from sandy soils, for instance.

Occupational exposure

Because of the extensive natural occurrence of crystalline silica in the Earth’s crust and the wide uses of the materials in which it is a constituent, workers may be exposed to crystalline silica in a large variety of industries and occupations. This includes activities that involve the movement of earth (e.g. mining, farming, construction, quarrying), disturbance of silica-containing products (e.g. demolition of masonry and concrete), and handling or use of sand- and other silica-containing products (e.g. foundry processes, such as casting, furnace installation and repair; abrasive blasting; production of glass, ceramics, abrasives, cement, etc.).

Activities such as abrasive blasting with sand, sawing brick or concrete, sanding or drilling into concrete walls, grinding mortar, manufacturing brick, concrete blocks, stone countertops or ceramic products, and cutting or crushing stone result in worker exposures to RCS dust. Industrial sand used in certain operations, such as foundry work and hydraulic fracturing (fracking), is also a source of RCS...
exposure.\textsuperscript{180} An exposure source that has gained particular attention recently is the use of artificial stone, for example for kitchen counter tops. Workers are exposed when cutting, grinding or polishing these materials.

According to a study commissioned by the European Commission, approximately 5.3 million workers in the EU were potentially exposed to RCS in 2006. Over 4 million of these workers are in the construction sector.\textsuperscript{181} A high proportion of workers were considered to still be at risk of being exposed above the considered OELs (14\% above 0.2 mg/m\textsuperscript{3}, 26\% above 0.1 mg/m\textsuperscript{3}, 41\% above 0.05 mg/m\textsuperscript{3}), and the estimated mean exposure was 0.07 mg/m\textsuperscript{3}. According to the study, the countries with the highest numbers of exposed workers were Spain (26.8\% of all EU workers), Germany (11.8\%), France (11\%) and the UK (9.4\%). Beside construction, the following industries were estimated to have the highest exposure levels compared to the other industry sectors as well as the highest numbers of exposed workers: manufacture of other non-metallic mineral products; other mining and quarrying; manufacture of basic metals; manufacture of fabricated metal products; and electricity, gas, steam and hot water supply.\textsuperscript{182} The IARC Monograph Volume 100C lists as main industries mines and quarries, foundries and other metallurgical operations, ceramics and related industries, construction, granite, crushed stone and related industries, sandblasting of metal surfaces and agriculture.

**Health effects**

Exposure to RCS in workplace air is associated with the development of silicosis, an irreversible scarring disease of the lung. Silicosis also appears to be a significant risk factor for the development of lung cancer. Exposure to RCS puts workers at risk for developing other serious diseases, including lung cancer, chronic obstructive pulmonary disease (COPD), kidney disease and autoimmune disease.\textsuperscript{183} Cancers other than that of the lung have not been as thoroughly researched.

**EU and IARC classification**

RCS dust (the respirable fraction of crystalline silica dust generated by a work process) is a process-generated substance that is not placed on the market and, as such, is not classified under the CLP Regulation. It is not subject to classification in accordance with Regulation (EC) No 1272/2008. It should be noted however that the common silica ‘polymorphs’ (i.e. different forms of crystallised silica) quartz, cristobalite and tridymite have all been classified according to the CLP Regulation by suppliers. Some suppliers have classified quartz and cristobalite as carcinogen category 1. No harmonised (mandatory) classification has been proposed. Quartz sand may be supplied, for example, for the glass industry. Crystalline silica is therefore to be considered as well as a process-generated substance as, for some uses, as a marketed substance.

It was deemed that there was sufficient evidence of the carcinogenicity of RCS dust in the first amendment of the CMD (now CMRD) and it was therefore appropriate to include work involving exposure to RCS dust generated by a work process in Annex I to Directive 2004/37/EC.\textsuperscript{184}

According to the IARC, there is sufficient evidence in humans for the carcinogenicity of crystalline silica in the form of quartz or cristobalite. Crystalline silica in the form of quartz or cristobalite dust causes cancer of the lungs.\textsuperscript{185} There is sufficient evidence in experimental animals for the carcinogenicity of quartz dust. There is limited evidence in experimental animals for the carcinogenicity of tridymite dust and cristobalite dust. The IARC concludes that crystalline silica in the form of quartz or cristobalite dust is carcinogenic to humans (Group 1).

---

\textsuperscript{180} See: \url{https://www.osha.gov/silica-crystalline}


\textsuperscript{183} See: \url{https://www.osha.gov/niosh/silica/symptoms/?CDC_AAref=Val=https://www.cdc.gov/niosh/topics/silica/risks.html}

\textsuperscript{184} See recital 18 to Directive 2017/2398: \url{http://data.europa.eu/eli/dir/2017/2398/oj}

\textsuperscript{185} International Agency for Research on Cancer. (2012). Arsenic, metals, fibres, and dusts. IARC Monographs on the evaluation of carcinogenic risks to humans (Vol. 100C). \url{https://publications.iarc.fr/120}
Legislation

Binding OELs for RCS were last set in 2017 with the first amendment to the CMD (now CMRD). Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with this directive by 17 January 2020.

19. **Trichloroethylene**

The chemical compound trichloroethylene is a halocarbon commonly used as an industrial solvent. It is a clear, colourless non-flammable liquid with a chloroform-like sweet smell. It should not be confused with the similar 1,1,1-trichloroethane, which is commonly known as chloroethene.

The IUPAC name is trichloroethene. Industrial abbreviations include TCE, trichlor, Trike, Tricky and tri.

**Use of trichloroethylene**

Trichloroethylene has been previously used as an anaesthetic, a stain remover in dry-cleaning, an ingredient in paints, adhesives and cleaners, and for degreasing metal parts, as well as for producing chlorinated chemicals.

Nowadays, TCE is mainly used in intermediate applications as well as in the metal cleaning and in the adhesives industries. According to REACH registration information available on ECHA’s website, trichloroethylene is manufactured and/or imported into the European Economic Area in volumes of 10,000 to 100,000 tonnes/year. Approximately 75% of the total production, as assessed in the 2010 IOM Study,\(^{187}\) was used in intermediate applications. Trichloroethylene use as a solvent has been declining and in 2007 solvent use accounted for approximately 25% of TCE production in the EU.

**Occupational exposure**

Exposure occurs mainly by inhalation. The most heavily exposed are those working in degreasing of metals and other materials.

It was estimated that approximately 74,000 workers in the EU were potentially exposed to trichloroethylene. An overview with estimations of the numbers of workers exposed in the different countries is provided on p. 99 and p. 111 of the staff working document.\(^{188}\) There were approximately 140,000 firms engaged in the ‘treatment and coating of metals’. Since trichloroethylene is an effective solvent for the cleaning of metals, it may be assumed that all of the enterprises would seek to use it. France, Germany, Italy, Poland, and the UK gathered together more than 60% of all firms. Czech Republic, Spain, Hungary, Portugal and Sweden each had more than 4,000 firms accounting for more than 20% of the total. The structure of the metal degreasing sector is not well known. In the case of the UK, the sector comprised a large number of small companies, with a high proportion having fewer than 20 workers.

**Health effects**

SCOEL identified trichloroethylene as a genotoxic carcinogen.\(^{189}\) Exposure to TCE is associated with increased risks of kidney, liver and biliary cancers and non-Hodgkin lymphoma. Exposures to high concentrations may also cause headaches, lung irritation, dizziness, or nerve, kidney and liver damage in the long term. SCOEL identified for trichloroethylene the possibility of significant uptake through the skin.

**EU and IARC classification**

Trichloroethylene has been classified as a Group 1 carcinogen by the IARC.\(^{190}\)

Trichloroethylene meets the criteria for classification as carcinogetic (category 1B) in accordance with Regulation (EC) No 1272/2008 and therefore is a carcinogen as defined in Directive 2004/37/EC.

---


\(^{189}\) Recommendation from the Scientific Committee on Occupational Exposure Limits for trichloroethylene, SCOEL/SUM/142: [https://ec.europa.eu/social/BlobServlet?docId=64056&langId=en](https://ec.europa.eu/social/BlobServlet?docId=64056&langId=en)

\(^{190}\) International Agency for Research on Cancer. (2014). *Trichloroethylene, tetrachloroethylene, and some other chlorinated agents. IARC Monographs on the evaluation of carcinogenic risks to humans* (Vol. 106). [https://publications.iarc.fr/Publications/MediaDownload/6688/c1deb8e919b750f2505d2f3b5a503e79f300d097.pdf](https://publications.iarc.fr/Publications/MediaDownload/6688/c1deb8e919b750f2505d2f3b5a503e79f300d097.pdf)
Trichloroethylene is registered under the REACH Regulation and is manufactured in and / or imported to the European Economic Area, at more than 10,000 tonnes per year. According to the harmonised classification and labelling approved by the EU, this substance may cause cancer, causes serious eye irritation, is suspected of causing genetic defects, is harmful to aquatic life with long-lasting effects, causes skin irritation, and may cause drowsiness or dizziness. Additionally, the classification provided by companies to ECHA in REACH registrations identifies that this substance may cause an allergic skin reaction.\textsuperscript{191}

\textbf{Legislation}

TCE has been added to Annex XIV to REACH and is therefore subject to REACH authorisation, as a result of which any use outside the terms of a case-by-case authorisation (or a valid pending application) was not permitted from 21 April 2016. ‘Intermediate’ use and exposures of workers resulting from process-generated substances are not in the scope of REACH authorisation. The decreasing use trends are a result of stringent requirements under the Solvents Emissions Directive, REACH and a voluntary industry commitment through the European Chlorinated Solvent Association (ESCA).

Binding OELs for trichlorethylene were last set in 2019 with the second amendment to the CMD (now CMRD).\textsuperscript{192} Member States should have brought into force the laws, regulations and administrative provisions necessary to comply with this directive by 21 February 2021.

\textsuperscript{191} ECHA substance infocard - trichloroethylene: \url{https://echa.europa.eu/es/substance-information/-/substanceinfo/100.001.062}
20. Ultraviolet radiation

Ultraviolet radiation (UVR) is a form of electromagnetic radiation that comes from the sun and man-made sources like tanning beds and welding torches (see section on artificial UVR).

There are also different types of UV rays, based on how much energy they have. The wavelength of UVR lies in the range of 100-400 nm and is further subdivided into UVA (315-400 nm), UVB (280-315 nm) and UVC (100-280 nm).

The amount of UV exposure a person gets depends on the strength of the rays, the length of time the skin is exposed, and whether the skin is protected with clothing or sunscreen.

Solar UVR (including ocular exposure)

Sunlight is the main source of UVR, even though UV rays make up only a small portion of the sun’s rays. Different types of UV rays reach the ground in different amounts. About 95% of the UV rays from the midday sun that reach the ground are UVA rays, with the remaining 5% being UVB rays. The strength of the UV rays reaching the ground depends on a number of factors, such as the following:

- **Time of day:** UV rays are strongest between 10:00 and 16:00. Season of the year: UV rays are stronger during spring and summer months. This is less of a factor near the equator. In summer, about 20-30% of the total daily amount of UVR is received between 11:00 and 13:00, and 75% between 9:00 and 15:00 (sun time not local time).
- **Season:** Seasonal variation in terrestrial UV irradiance, especially UVB, at the Earth’s surface is significant in temperate regions but much less nearer the equator.
- **Geographic latitude, distance from the equator:** Annual UVR exposure dose decreases with increasing distance from the equator.
- **Altitude:** Total solar irradiance and the relative contributions of different wavelengths vary with altitude. More UV rays reach the ground at higher elevations. In general, each 300-metre increase in altitude increases the sunburning effectiveness of sunlight by about 4%.
- **Clouds:** The effect of clouds can vary, but what is important to know is that UV rays can get through to the ground, even on a cloudy day. Clouds influence UV ground irradiance, through reflection, refraction, absorption and scattering, and may increase or, more usually, decrease UV ground irradiance. Complete light cloud cover prevents about 50% of UVR energy from reaching the surface of the Earth.
- **Reflection off surfaces:** UV rays can bounce off surfaces like water, sand, snow, pavement and even grass, leading to an increase in UV exposure.
- **Contents of the air:** Ozone in the upper atmosphere, for example, filters out some UVR.

Clouds attenuate solar radiation, although their effect on infrared radiation is greater than on UVR. Climate change will also influence surface UVR through changes induced mainly to clouds and the ability of the Earth’s surface to reflect light. Aerosols and air pollutants are also expected to change in the future. These factors may result in either increases or decreases of surface UV irradiance, through absorption or scattering. As ozone depletion becomes smaller, these factors are likely to dominate future UVR levels.

Reflection

Reflection of sunlight from certain ground surfaces may contribute significantly to the total amount of scattered UVR. In some settings, workers may be exposed to radiation by reflection or scattering from adjacent surfaces. Ground reflectance plays a major role in exposure to UVB of all exposed body parts, including the eye and shaded skin surfaces, particularly with highly reflective surfaces such as snow.

The contribution of reflected UVR to a person’s total UVR exposure varies in importance with several factors. A grass lawn scatters 2-5% of incident UVB radiation. Sand reflects about 10-15%, so sitting under an umbrella on the beach can lead to sunburn both from scattered UVB from the sky and reflected UVB from the sand. Fresh snow may reflect up to 85-90% of incident UVB radiation while water, in particular white foam in the sea, may reflect up to 30%. Ground reflectance is important, because parts of the body that are normally shaded are exposed to reflected radiation.
The WES considers different reflective surfaces, such as water, reflective roofs, sand and snow.

**Measurement of UVR**

Ambient UVR may be measured in purely physical units or weighted using an erythemal response function to give biologically effective UVR, expressed as joules per square metre (J/m$^2$), minimal erythema dose (MED), standard erythema dose (SED) or the solar UV index.\(^{193}\)

A unit of effective dose commonly used is the MED. One MED has been defined as the lowest radiant exposure to UVR that is sufficient to produce erythema with sharp margins 24 hours after exposure. Another endpoint often used in cutaneous photobiology is a just-perceptible reddening of exposed skin; the dose of UVR necessary to produce this ‘minimal perceptible erythema’ is sometimes also referred to as an MED. In unacclimatised, white-skinned populations, there is an approximately fourfold range in the MED of exposure to UVB radiation. The cumulative annual exposure dose of solar UVR varies widely among individuals in a given population, depending to a large extent on the occupation and extent of outdoor activities. For example, it has been estimated that indoor workers in mid-latitudes (40-60 °N) receive an annual exposure dose of solar UVR to the face of about 40-160 times the MED, depending on their level of outdoor activities, whereas the annual solar exposure dose for outdoor workers is typically around 250 times the MED. Because few actual measurements of personal exposures have been reported, these estimates should be considered to be very approximate.

The SED has been developed as an erythemally weighted measure of radiant exposure, equivalent to 100 J/m$^2$. The SED is independent of skin type and a particular exposure dose in SED may cause erythema in fair skin but none in darker skin.

The global solar UV index was developed as an easy-to-understand measure of biologically effective UVR to promote public awareness of the risks of UVR exposure and to promote sun protection. The values of the index range from 0 upwards — the higher the index value, the greater the potential for damage to the skin and eyes, and the less time it takes for injury to occur. Weather forecasts in many countries include a forecast of the solar UV index to guide public sun exposure.\(^{194,195}\)

- MED: the dose of UVR required to produce a barely perceptible erythema in people with skin type 1 (200 J/m$^2$ of biologically effective UVR).
- SED: erythemally weighted radiant UVR equivalent to 100 J/m$^2$.
- Solar UV index: time weighted average effective UV irradiance in W/m$^2$ multiplied by 40 (Watts = joules/sec).

Both the American Conference of Governmental Industrial Hygienists (ACGIH) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) propose an OEL of 3 mJ/cm$^2$ (effective radiant energy).\(^{196}\)

Measures can be taken to avoid solar UV exposure. Sunscreens can be applied to control the dose of UVR to exposed skin. While undoubtedly useful when sun exposure is unavoidable, their use may lead to a longer duration of sun exposure. The WES considers the use of sunscreens, protective clothing, shading and organisational measures to avoid working at hours of peak exposures.

---


**Occupational exposure to solar UV**

Exposure to solar UV radiation can occur in many sectors and occupations, including agriculture, horticulture, viticulture and forestry, animal husbandry, mining, natural stone and mineral processing, woodworking and wood processing, metal construction, construction and related trades, roofing, renewable energy technology, utilities (e.g. line workers), waste management, transport and logistics, delivery services, fisheries and ship industry, police and armed forces.

A 2021 study based on occupation-specific dosimetric measurements of 45,000 measurement days in 176 occupations and sub-occupations estimated the number of workers that may be exposed to UVR as 36.1 million in the EU-28 and more than 500 million in the world, respectively. The study is based on German regulations for occupational health prevention: it must be offered to every worker whose activities meet certain criteria. Regarding UVR exposure, these include assessing the exposure period of the months from April to September, and the daily period from 11:00 to 16:00 (CEST). If a worker has worked outdoors for more than one hour on more than 50 days during this period, he or she must be offered occupational health prevention. For example, occupations that were not previously in the focus, such as professional drivers in freight transport, surveyors, and warehouse and transport workers, come into consideration. This includes all occupations with annual exposures of more than 150 SED (1 SED = 100 J/m²).197

Another study assessed the differences of exposure to masons in different European countries from different regions and showed that outdoor workers from EU countries included in the study were exposed to high levels of occupational solar UVR, exceeding the OELs for solar UVR exposure, considered to be 1-1.33 SED/day in the period from May to September.198

**Artificial UVR (including ocular exposure)**

Artificial sources for UVR include the following:

- Sunlamps and sunbeds (tanning beds and booths): The amount and type of UVR someone is exposed to from a tanning bed (or booth) depends on the specific lamps used in the bed, how long a person stays in the bed, and how many times the person uses it. Most modern UV tanning beds emit mostly UVA rays, with the rest being UVB.

- Phototherapy (UV therapy): Some skin problems (such as psoriasis) are helped by treatment with UV light. For a treatment known as PUVA, a drug called a psoralen is given first. The drug collects in the skin and makes it more sensitive to UVR. Then the patient is treated with UVA radiation. Another treatment option is the use of UVB alone (without a drug).

- Black-light lamps: These lamps use bulbs that give off UV rays (mostly UVA). The bulb also gives off some visible light, but it has a filter that blocks most of that out while letting the UV rays through. These bulbs have a purple glow and are used to view fluorescent material. Bug-zapping insect traps also use ‘black light’ that gives off some UV rays, but the bulbs use a different filter that causes them to glow blue.

- Mercury-vapour lamps: These can be used to light large public areas such as streets or gyms. They do not expose people to UV rays if they are working properly. They are actually made up of two bulbs: an inner bulb that emits light and UV rays, and an outer bulb that filters out the UV. UV exposure can only occur if the outer bulb is broken. Some mercury-vapour lamps are designed to turn themselves off when the outer bulb breaks. The ones that don’t have this feature are only supposed to be installed behind a protective layer or in areas where people wouldn’t be exposed if part of the bulb breaks.

- High-pressure xenon and xenon-mercury arc lamps, plasma torches and welding arcs: Xenon and xenon-mercury arc lamps are used as sources of light and UV rays for many things, such as UV ‘curing’ (of inks, coatings, etc.), disinfection, to simulate sunlight (to test solar panels, for


example), and even in some car headlights. Most of these, along with plasma torches and welding arcs, are mainly of concern in terms of workplace UV exposure.\footnote{199}

**Occupational exposure to artificial UVR**

Workers in certain occupations are exposed to significant levels of artificial UVR. These include welders, staff in television studios and on theatre stages, scientific and medical workers, and workers in the graphics industry. There are more than 1.2 million workers estimated to be exposed to artificial UVR in the EU-27.\footnote{200}

**Welding**

Acute overexposures to the eyes are common among electric arc welders. As well as the actual workers performing the welding tasks, their co-workers (bystanders) may also be exposed to UVR. Welding processes are divided in two broad categories: gas welding and electric arc welding. Mainly arc welding produces hazardous levels of UVR, the quality and quantity of which depend primarily on the arc current, shielding gas and the metals being welded. For example, aluminium welding produces much more UVR than the arc welding of steel using the same arc current. At European worksites, welders are the largest occupational group exposed to hazardous artificial sources of UVR. Generally, UVR irradiance levels from welding arcs are very high, and the permissible exposure duration before exceeding the ELVs is typically less than one minute. Studies of worker exposure from welding arcs have shown that the UVR exposure of welders can exceed daily OELs to the unprotected eye and skin by several thousandfold.\footnote{201}

**Photochemical hardening**

UVR is also used in many different industries, yet there is a paucity of data concerning human exposure from these applications. Individuals exposed to lighting from fluorescent lamps may typically receive annual exposure doses of UVR in the range of 0-30 times the MED, depending on illuminance levels and whether or not the lamps are housed behind plastic diffusers. It is also worth noting that tungsten-halogen lamps used for general lighting may emit broad-band UVR (including UVC) when not housed behind a glass filter.

UV is used in many industrial processes for photochemical hardening (‘drying’), such as the photocuring of lacquers, inks and glues. Hardening of glues and plastics is often performed with UVA sources, where the exposure is relatively low. However, for special applications, sources that also emit UVB and UVC radiation are used. These processes often use high-power (several kilowatts) lamps. These sources can emit very high levels of UVR, and therefore the industrial process is generally housed in interlocked assemblies and behind opaque baffles to prevent hazardous exposure to personnel during normal work. Nevertheless, UVR can escape via small slits at openings and thus expose the worker.

UV lasers and light emitting diodes (LEDs) are also used in electronics and in the printing industry. Modern equipment is normally designed to completely enclose UV sources, however, during maintenance and service potentially hazardous UV exposures can occur.

**Health and dental care**

Other sources of exposures to UVR include medical and dental applications. UVR has been used for several decades to treat skin diseases, notably psoriasis. A variety of sources of UVR are used, emitting either broad-band UVA or narrow-band UVB. Staff in hospitals who work with unenclosed phototherapy equipment are at potential risk of overexposure unless protective measures are taken. A typical dose in a single course of UVB phototherapy can be in the range of 200-300 times the MED. Laser devices operating in the UVR spectral region are used in medical environments for diagnostic and treatment


Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

procedures. For example, the argon fluoride laser operating at 193 nm is commonly used for corneal refractive surgery procedures.

UVR is also widely used in dermatological treatment facilities. The spectral emission of xenon lamps closely matches that of solar radiation. This enables their use as solar radiation simulators, for example in investigating patients with skin diseases induced by solar radiation. Large amounts of UVA, UVB and UVC radiation are emitted by unfiltered xenon lamps, so they can present a significant health hazard if incorrectly used.

Disinfection and sterilisation

UVR is broadly used for the disinfection and sterilisation of substances and room air, for example in the food industry to disinfect containers, tools and work areas. Since UVC in the wavelength range of 250-265 nm is the most effective for inactivating viruses and bacteria, low-pressure mercury discharge lamps are the most commonly used for these purposes. Exposure at short distances to bare UVC lamps exceeds the exposure limit for the eye and the skin in only a few seconds. In some applications, lamps are used during the night when nobody occupies the room, and motion detectors switch off the lamp if somebody enters the room. A technically simple solution is to house germicidal lamps behind metal barriers, normal glass or plastic that provides adequate protection to workers.

Research laboratories

Laboratory scientists and other staff engaged in photobiology, photochemistry or laser materials processing use various UVR sources. In these applications, high-power UVR lamps and lasers used in various research laboratories may cause occupational health risks to the skin and the eyes of the research personnel.

Material inspection

UVR is used in materials inspection by inducing fluorescence. When fluorescent liquid is applied, it remains in cracks of metal pieces that become visible during irradiation with UVA radiation. Fluorescent lamps produce a wide range of spectral emissions covering the visible radiation, as well as UVA and UVB regions. High power sources for metal crack inspection can exceed the exposure limits of the skin and the eyes at typical workplaces. In such cases, the hands should be protected by wearing of gloves, and the eyes can be protected by shielding against a direct line of sight to the lamp (e.g. by mounting the lamp below eye level).

Other applications where UVA induces fluorescence are inspection tasks of fabrics. UVR emissions of low-power UVR lamps are usually below the exposure limits for typical exposure distances and durations.

Indoor tanning facilities

Indoor tanning facilities may comprise 20 or more UVA tanning appliances, thus potentially exposing operators to high levels (> 20 W/m²) of UVA. Significant occupational exposure to UVR from solaria may occur in shops where sunbeds are purchased for home use. Typically, shops have tens of UV tanning appliances, sometimes all UV lamps are switched on, hence exposing staff to high levels of UVR.

Indoor and outdoor lighting

Quartz halogen or tungsten halogen lamps are widely used in special illumination applications, for instance for specialised task lighting demanding high localised illumination and in clinical instruments. Halogen lamps operate at a higher temperature than regular incandescent lamps and emit a broad spectrum of light, which includes UVR.

High-intensity discharge (HID) mercury lamps are used for roadway lighting, and for lighting of construction sites. UVR is usually absorbed by the outer envelope of the lamp, but if the envelope is broken, the internal UV discharge lamp may continue to operate and severe exposure of the eye and skin can occur, and also put at risk maintenance workers who replace lamps and lamp envelopes in areas such as sporting halls and large industrial buildings.
Floodlighting in studios and entertainment facilities

High power tungsten halogen and metal halide lamps are used for spotlighting in television studios and on theatre stages. In some working situations, such as those typical for news readers and reporters, staff can be exposed to levels of UVR exceeding exposure limits for the eyes and skin.

Health effects of solar and artificial UV

Effects on the skin

UV rays don’t have enough energy to penetrate deeply into the body, so their main effect is on the skin.

- **UVA rays** have the least energy among UV rays. These rays can cause skin cells to age and can cause some indirect damage to cells’ DNA. UVA rays are mainly linked to long-term skin damage such as wrinkles, but they are also thought to play a role in some skin cancers.

- **UVB rays** have slightly more energy than UVA rays. They can damage the DNA in skin cells directly, and are the main rays that cause sunburns. They are also thought to cause most skin cancers. Because UVR wavelengths between about 295-320 nm (UVB radiation) in the terrestrial solar spectrum are thought to be those mainly responsible for adverse health effects, several studies have focused on this spectral region.

- **UVC rays** have more energy than the other types of UV rays. Fortunately, because of this, they react with ozone high in our atmosphere and don’t reach the ground, so they are not normally a risk factor for skin cancer from natural UVR. But UVC rays can also come from some man-made sources, such as arc welding torches, mercury lamps, and UV sanitising bulbs used to kill bacteria and other germs (such as in water, air and food, and on surfaces).

The most exposed skin surfaces, such as the nose, tops of the ears and forehead, have levels of UVB exposure that range up to one order of magnitude relative to that of the lesser exposed areas, such as underneath the chin.

Most skin cancers are a result of exposure to the UV rays in sunlight. Both basal cell and squamous cell cancers (the most common types of skin cancer) tend to be found on sun-exposed parts of the body, and their occurrence is typically related to lifetime sun exposure. The risk of melanoma, a more serious but less common type of skin cancer, is also related to sun exposure. Non-melanoma skin cancer is the most common cancer in western countries. Around 90% of skin cancer cases are the non-melanoma types.

Cancer of the lip has also been associated with outdoor occupations in several descriptive studies.

Skin cancer has also been linked to exposure to some man-made sources of UV rays.

In addition to skin cancer, exposure to UV rays can cause other health problems:

- UV rays, either from the sun or from artificial sources, can cause sunburn.

- Exposure to UV rays can cause premature ageing of the skin and signs of sun damage such as wrinkles, leathery skin, liver spots, actinic keratosis and solar elastosis.

- Exposure to UV rays can also weaken the immune system, so that the body has a harder time fending off infections. This can lead to problems such as reactivation of herpes triggered by exposure to the sun or other sources of UV rays. It can also cause vaccines to be less effective.

Health effects on the eye (ocular UV)

UV rays can also cause eye problems. They can cause the cornea (on the front of the eye) to become inflamed or burned. They can also lead to the formation of cataracts (clouding of the lens of the eye) and pterygium (tissue growth on the surface of the eye), both of which can impair vision.

If adequate eye protection is not worn, excessive exposure to intense sunlight and/or to any artificial source of light, such as welding torches and sun lamps, can lead to burning of the delicate tissue in the eye. The highest risk comes from direct exposure to sunlight, light reflected from snow and snow-covered surfaces, or when flying above clouds with light reflected from cloud surfaces. The adverse effects on the skin are minor compared to those on the eye.

---

202 OSHwiki, *UV radiation at work and health*, 2013. Available at: https://oshwiki.eu/wiki/UV_radiation_at_work_and_health
health effects that may occur are erythema (sunburn), photokeratitis (a feeling of sand in the eyes), skin cancer, increased skin pigmentation (tanning), cataracts and retinal burns. The retina is mostly spared the harmful effects of UV because this part of the electromagnetic spectrum is absorbed by the front part of the eye. However, the high-energy violet and blue parts of the sunlight spectrum are considered harmful to the retina.203

Outdoor workers are at risk of damage to the eyes from UVR from the sun. Excessive UVR exposure over a short period of time causes photokeratitis and photoconjunctivitis, which may be compared to sunburn. Photokeratitis is an inflammation of the cornea, while photoconjunctivitis refers to an inflammation of the conjunctiva, the membrane that lines the inside of the eyelids and eye socket. Both conditions can be very painful; however, they are reversible and do not seem to result in any long-term damage to the eye or vision. People who stare fixedly at the sun without adequate protection can incur retinal damage (blue-light hazard).204

Repeated exposure may cause non-malignant clinical lesions of the cornea and conjunctiva such as climatic droplet degeneration (discrete areas of yellow protein deposits in the cornea and conjunctiva), pterygium (an overgrowth of the conjunctiva on to the cornea) and, probably, pinguecula (small yellow growths in the conjunctiva).

Basal cell carcinoma and squamous cell carcinoma are the two common malignant tumours of the eyelid. Both epidemiological and molecular studies support the association of these skin cancers with exposure to UVR. The eyes also have melanin-producing cells and can develop melanoma. Eye melanoma is also called ocular or uveal melanoma.

Research has also shown that UVR increases the likelihood of certain cataracts. Cataracts are a form of eye damage in which a loss of transparency in the lens of the eye clouds vision. Other kinds of eye damage include pterygium (tissue growth that can block vision), skin cancer around the eyes, and degeneration of the macula (the part of the retina where visual perception is most acute).

Simple measures, such as appropriate clothing, wearing hats, and using UV-blocking spectacles, sunglasses or contact lenses are effective measures for UV protection. Goggles, spectacles, visors or face shields, which absorb UVR, should be worn where there is a potential eye hazard.

The highest levels of UVR commonly existing in indoor work occur during electric arc welding, which produces high levels of all wavelengths of UVR, including high irradiance in the UVC region. Even in the non-welding areas of factories where welding equipment is used, ambient UVR levels can exceed OEL values during a working day. Therefore, not only the welder needs to be protected but also helpers should wear PPE or workplaces should be shielded.

The WES considers protection to the eyes, such as goggles or sunglasses.

**EU and IARC classification**

Solar radiation was classified by the IARC as Group 1 as early as 1992. The IARC concluded from the revision of the initial assessment205 in 2012 that

- There was sufficient evidence in humans for the carcinogenicity of solar radiation. Solar radiation causes cutaneous malignant melanoma, squamous cell carcinoma of the skin and basal cell carcinoma of the skin. A positive association has been observed between exposure to solar radiation and cancer of the lip, conjunctival squamous cell carcinoma and ocular melanoma, based primarily on results observed in the choroid and the ciliary body of the eye.
- There was sufficient evidence in humans for the carcinogenicity of the use of UV-emitting tanning devices. Use of UV-emitting tanning devices was therefore classified as carcinogenic to humans (Group 1).

---


Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

- There was sufficient evidence in experimental animals for the carcinogenicity of solar radiation, broad-spectrum UVR, UVA radiation, UVB radiation and UVC radiation. Ultraviolet radiation (bandwidth 100-400 nm, encompassing UVC, UVB and UVA) was therefore classified as carcinogenic to humans (Group 1).
- There was sufficient evidence for ocular melanoma in welders, and that UV emissions from welding are carcinogenic to humans (Group 1). There was sufficient evidence in humans for the carcinogenicity of UV emissions from welding.

Legislation

On 5 April 2006, the European Parliament and Council adopted Directive 2006/25/EC on the minimum requirements to protect workers’ safety and health from artificial optical radiation, which includes artificial UVR. The directive lays down minimum requirements to protect workers from the risks associated with optical radiation, in particular damage to the eyes and to the skin. The directive establishes ELVs based on established health effects and biological considerations. With regard to artificial UVR, the ELVs concern non-coherent UVR as well as coherent UVR, that is, from laser. The Member States had to transpose Directive 2006/25/EC into national law by 27 April 2010. Exposure Limit Values (ELVs) are established for artificial UVR sources only in Directive 2006/25/EC. They are different for non-coherent UVR and coherent UVR (laser).

21. Ionising radiation

Ionising radiation can be described as the transfer of energy in the form of particles (such as alpha and beta particles) or electromagnetic waves (such as X-rays and gamma rays) of a wavelength of 100 nm or less or a frequency of 3 x 1,015 Hz or more capable of producing ions directly or indirectly. Ionising radiation can occur naturally (e.g. from the radioactive decay of natural radioactive substances such as radon gas and its decay products) or it can be generated artificially (e.g. man-made radioactive substances or the operation of certain electrical equipment, such as X-ray sets, which emit ionising radiations. Radioactive substances give out radiation all of the time. There are three types of nuclear radiation: alpha, beta and gamma. Alpha is the least penetrating, while gamma is the most penetrating). A criterion and three principles for control (time, distance and shielding) are used to ensure that ionising radiation exposure is kept to a minimum.207

Use of ionising radiation

Ionising radiation has many uses in industry, such as energy production, manufacturing, medicine and research. Ionising radiation sources are used in medicine (for diagnosis and treatment), industry (for measurement and other purposes as well as for producing energy), and in research and teaching.

Medical use

The medical uses of radiation include diagnostic examinations and therapy. X-rays are used in many medical and technical applications. The most common are diagnostic X-ray examinations of the human body and the analysis of materials. In X-ray therapy, the biological effect of X-rays is used to destroy malignant tissue. It is applied mainly to treat cancer patients, when high doses are delivered to a limited area of the body, with restricted irradiation of adjacent tissue. The average levels of radiation exposure due to the medical uses of radiation have been increasing, in particular due to increasing use of computer tomography (CT), angiography and interventional procedures in developed countries. CT scanning has become widely available in many developed countries. The effective dose per examination is considerably higher than that from most conventional radiographic procedures, and its use is increasing.

Fluoroscopy results in much higher doses than radiography. The doses may vary widely: modern equipment with image amplifiers results in lower doses than older equipment with fluorescent screens, but high doses may still be received. Advances in technology have facilitated the development of increasingly complex radiological procedures for angiography and interventional radiology.

Manufacturing

The use of ionising sources in industry is very heterogeneous. Ionising radiation is used in level meters, for example. It can be found in breweries where on the production assembly line an ionising radiation source is installed on one side of the line and a detector on the other.

Ionising radiation is often used for non-destructive testing. The method is similar to diagnostic use in medicine. Ionising radiation penetrates pipes, tubes, casts or other products where there is a detector on the other side, usually film sensitive to ionising radiation. The image on the film shows if there are any defects in the object such as cracks, homogeneities or foreign material.

A nuclear density gauge is a tool used in civil construction and the petroleum industry as well as for mining and archaeology purposes. It consists of a radiation source that emits a directed beam of particles and a sensor that counts the received particles that are either reflected by the test material or pass through it. By calculating the percentage of particles that return to the sensor, the gauge can be calibrated to measure the density and inner structure of the test material.

Occupational exposure

Occupational exposure to radiation occurs during nuclear power production and fuel recycling, military activities, industrial operations, flying and medical procedures.

207 OSHwiki, Ionising radiation at workplaces, 2016. Available at: https://oshwiki.eu/wiki/Ionising_radiation_at_workplaces
Naturally occurring radioactivity

In some industries, accumulation of naturally occurring radioactivity can occur. In some cases, this natural radioactivity can accumulate. It accumulates in the oil and gas industry. Solids may contain naturally occurring radioactive material that can accumulate in vessels or deposit on internal surfaces. Workers working in the vicinity of such places are exposed to elevated levels of ionising radiation. In the zircon sand industry, workers might be exposed to naturally occurring radiation since elevated levels of uranium and thorium can be found in zircon.

Security checks at airports

Another source of ionising radiation is X-ray checking of baggage at the airport. Passenger baggage is put on a conveyer and sent through an X-ray device. The method is very similar to that used in medicine.

Industrial radiography

The practices where workers receive the highest doses are industrial radiography, where annual doses between 5 and 10 millisieverts (mSv) are not uncommon, compared to the radiation in everyday life which is approximately 2.4 mSv in a year (in the EU between 2 and 5.5 mSv). Staff involved in radiotherapy with neutrons are exposed mainly to γ- and β-rays due to activation of the room and equipment.

Nuclear industry

In the nuclear industry, workers receive doses mainly during maintenance works during outages. A dose of a few millisieverts is not unusual and in some cases workers receive doses close to the regulatory limit. Occupational exposure to neutrons constitutes a small fraction of the total effective dose and occurs mainly in the nuclear industry. Neutron sources are also used to chart progress in the search for gas and oil resources.

Medical use

In medicine, the practice that requires special care is interventional cardiology. During an interventional cardiology procedure, the doctor inserts a catheter into a vein. The procedure has a long duration and the doctor has to use X-rays many times to see how it proceeds in the patient body. The whole medical team can be exposed to high doses. The annual doses to the team members are a few millisieverts. But of even greater concern are doses to the eye lens. Among cardiologists performing interventional cardiology procedures, a big increase in the incidence of cataracts has been observed.

Flight crew

The exposure of commercial aircraft crews to neutrons depends on the flight route and on the number of flight hours with secondary neutrons from galactic cosmic rays contributing about 10-15% of the dose at an altitude of 10 km.

An overview table of average annual exposure doses in different professions is provided in the IARC Monograph Volume 100D on radiation.

Health effects

Ionising radiation attacks the cells of the body by producing chemical changes in the cell DNA, leading to abnormal cell growth. The effect on body tissues will depend on the type of radiation, the dose and duration of exposure and whether the source is internal or external to the body.

X-radiation and γ-radiation cause cancer of the salivary gland, oesophagus, stomach, colon, lung, bone, basal cell of the skin, female breast, kidney, urinary bladder, brain and CNS, thyroid, and leukaemia (excluding chronic lymphocytic leukaemia). Also, positive associations have been observed between X-radiation and γ-radiation and cancer of the rectum, liver, pancreas, ovary and prostate, and non-Hodgkin lymphoma and multiple myeloma.
**EU and IARC classification**

X-radiation and γ-radiation were classified as Group 1 carcinogens by the IARC in 2000. In its revision in 2012, the IARC concluded that all types of ionising radiation are carcinogenic to humans (Group 1).

**Legislation**

Every country should have legislation where exposure limits for workers are defined. The limits are established in numerous epidemiological studies of survivors of Hiroshima and Nagasaki atomic bomb explosions, from many accidents with ionising radiation sources and from studies of the large cohorts of workers in the nuclear industry. The dose limits are defined in publications of the International Commission on Radiological Protection (ICRP). The last recommendations on dose limits were published in 2007 (100 mSv/5 years (which is 20 mSv/year) or 50 mSv/year). The ICRP is in the process of review and revision of the system that will update the 2007 General Recommendations in ICRP Publication 103. The most important dose limit is the annual dose limit of 20 mSv. It means that a worker can receive a dose of 20 mSv per year from ionising sources they are working with.

There is natural background radiation due to radioactivity in soil, water, air, food and so on. On average, the annual natural background dose is around 2 mSv. A worker using ionising radiation sources can therefore receive 10 times the dose of the natural background at the workplace. For women, there are special limitations during pregnancy and breast feeding. The dose limits for apprentices aged 18 years or over and students aged 18 years or over who, in the course of their studies, are obliged to use sources shall be the same as the dose limits for exposed workers. The limit for the effective dose for apprentices aged between 16 and 18 years and for students aged between 16 and 18 years who, in the course of their studies, are obliged to use sources shall be 6 mSv per year. All organs and tissues are not equally sensitive to ionising radiation. Some tissues are more sensitive than others (very high radiosensitivity: small intestines, blood, bone marrow, lymphoid organs, testes and ovaries, embryonic tissue; high radiosensitivity: bladder, uterus, lens and cornea of eye, skin, gastrointestinal organs). Also, during the working process, only specific organs or tissues can be exposed to radiation and not the whole body. Due to these facts, the doses to the skin and eye lens are different. The annual skin dose is limited to 500 mSv and to the eye lens to 20 mSv.

---


22. **Leather dust**

Dust is produced as a result of many different industrial processes throughout the leather and footwear manufacturing supply chain, in particular in the dustier operations of cutting, trimming or scouring the leather. Leather dust can contain both fibres and grains; the fibres can vary from 30-1200 μm in length and from 10-30 μm in diameter. Grains are usually < 10 μm in diameter. In several surveys in Italy, more than 50% of the total dust in tanneries was reported as having a particle diameter of < 5 μm.

**Occupational exposure**

The leather trades in which workers are exposed to leather dust include shoemaking and the production of leather clothes and other leather goods. The workers who are most exposed are those involved in cutting, assembly, buffing, finishing and shining. Work in leather tanning and processing may involve exposure to a wide range of chemicals. Some of these are carcinogens or suspected carcinogens, such as chromium(VI) salts, vegetable tannins, chlorophenols, aniline dyes, formaldehyde, methyl mercury, arsenic, benzene and chlorinated organic solvents.

Dust is also produced during several processes in tanning operations: chemical dust can be produced during the loading of hide-tanning drums; and leather dust impregnated with chemicals is produced during some mechanical operations, including buffing. Especially at shaving and buffing stages, a huge amount of dust is generated around the rotating drums. Leather dust may contain agents originating from the processing of leather in tanneries. Levels of chromium(VI) compounds in leather dust are usually very low. Leather dust may also contain dyes. Dyes that have been used in the boot and shoe industry include seven dyes classified by the IARC as Group 2B (possibly carcinogenic to humans): CI Acid Red 114 (CAS, 6459-94-5), auramine (CAS, 492-80-8), benzyl violet 4B (CAS, 1694-09-3), Trypan blue (CAS, 72-57-1), Ponceau MX (CAS, 3761-53-3), Ponceau 3R (CAS, 3564-09-8), and Rosaline (CAS, 632-99-5) in Magenta.

**Health effects**

There is strong evidence that exposure to leather dust causes cancer of the nasal cavity and paranasal sinuses. Recent studies found little or no association of bladder cancer with the leather industry when tanning was not considered.

Chromium(III) compounds are used for leather tanning, and chromium may be released during use of leather goods. In certain instances, small amounts of chromium(VI) can be formed and released. Both trivalent and hexavalent chromium can elicit allergic skin reaction in chromium-sensitised subjects, the latter being significantly more potent. Leather dust may also contain moulds or mites with allergenic properties.

**EU and IARC classification**

Leather dust was classified by the IARC as carcinogenic to humans (Group 1). The IARC concluded that there was sufficient evidence in humans for the carcinogenicity of leather dust.

**Legislation**

There is currently no specific legislation at EU level that regulates exposure to leather dust. In March 2014, a restriction was introduced in REACH Annex XVII. From May 2015, leather articles coming into contact with the skin shall not be placed on the market where they contain chromium(VI) in concentrations equal to or greater than 3 mg/kg (0.0003%) of the total dry weight of the leather. The restriction does not apply to second-hand articles, but it impacts a wide range of products such as footwear, gloves, clothing and accessories (hats, belts, bracelets, wallets, bags and suitcases).

---


23. Wood dust

Wood dust is a process-generated mixture that workers may be exposed to when wood or wood-containing materials are processed, for example in construction and furniture-making. Wood dust, generated in the processing of wood for a wide range of uses, is a complex mixture. Its composition varies considerably according to the species of tree being processed. Wood dust is composed mainly of cellulose (approximately 40-50%), polyoses, lignin, and a large and variable number of substances of lower relative molecular mass that may significantly affect the properties of the wood. Out of 12,000 different species of trees, only about 800 are coniferous or softwoods, but roughly two-thirds of the wood used commercially worldwide belongs to the group of softwoods.

**Occupational exposure**

Exposure to hardwood dust occurs mainly in the wood working industry and furniture manufacturing and construction sectors. The highest exposures to wood dust have generally been reported in wood furniture and cabinet manufacture, especially during machine sanding and similar operations. Notable exposure levels have also been measured in the finishing departments of plywood and particleboard mills, where wood is sawn and sanded, and in the workroom air of sawmills and planer mills near chippers, saws and planers. Exposure to wood dust also occurs among workers in joinery shops, window and door manufacture, wooden boat manufacture, installation and refinishing of wood floors, pattern and model making, pulp and paper manufacture, construction carpentry and logging. The size of the dust particles produced, the amount of dust and resultant exposure to the person working in these areas depends on several factors, including the equipment being used, the ventilation and extraction system in place, the state and type of timber, the general ventilation in the area and any PPE that may be used. Construction woodworkers may be exposed to asbestos and silica in their work environment. Many of them also varnish wooden floors with solvent- or water-based varnishes, some of which may release formaldehyde.

Over 3 million EU workers (3,333,000) are potentially exposed in over 340,000 companies, mostly SMEs, with a production value of around €230 billion/year. Regarding the manufacture of wood products industry, a report commissioned to IOM by the European Commission\(^\text{215}\) estimates that more than 88% of enterprises have between one and nine employees, while only 1.5% have between 50 and 250 employees. The furniture manufacturing sector is similarly mostly composed of very small enterprises (86% with one to nine employees) and few large companies (2.3% with 50 to 250 employees). According to the report, the countries with the highest numbers of exposed workers are Germany (19.8% of all EU workers), Spain (12.2%), the UK (19.9%), Italy (9.9%) and Poland (9.3%). An estimate of number of exposed workers by country is included in the impact assessment document for the first amendment of the CMD (now CMRD) (p. 152).

The wood species used in wood-related industries vary greatly by region and by type of product. Both hardwoods and softwoods (either domesticely grown or imported) are used in the manufacture of furniture. Logging, sawmills, plywood and particleboard manufacture generally involve the use of trees grown locally. The staff working document accompanying the first amendment of the CMD (now CMRD)\(^\text{215}\) assesses that more than 75% of workers exposed to wood dust are exposed to both hardwood and softwood dusts,\(^\text{216}\) and the prevention of the risks posed by hardwood dust will also include softwood dust. It also stresses that it is impossible at the moment for two essential reasons to clearly identify the particular role of each type of wood in the genesis of cancer: (i) too few studies have addressed this problem; and (ii) both types of wood are usually used in most wood-related fields of activity and workers have been exposed to both, making reference to a SCOEL assessment.\(^\text{217}\)

---


Within the furniture manufacturing industry, exposure may also occur to solvents and formaldehyde in
-glues and surface coatings. The manufacture of plywood and particle board may result in exposure to
-formaldehyde, solvents, phenol, wood preservatives and engine exhausts. Sawmill workers may also
-be exposed to wood preservatives and fungal spores. Wood preservatives used include chlorophenol
-salts in sawmills and organochlorine pesticides in plywood mills.\textsuperscript{218}

\textbf{Health effects}

Hardwood dust may cause sinonasal and nasopharyngeal cancers. There was weaker evidence for
-other sites such as the pharynx, larynx and lung. In addition, hardwood dust may cause non-malignant
-respiratory health problems, including occupational asthma. Occupational exposure to irritative or
-allergic wood dust may lead to bronchial asthma, rhinitis, allergic alveolitis, organic dust toxic syndrome
(ODTS), bronchitis, allergic dermatitis and conjunctivitis. An increased risk of adenocarcinoma of the
-sinonasal cavity is an important and serious problem associated with occupational exposure to wood
dust. Other effects may be caused by microorganisms on the wood, mainly mould fungi and their
-metabolic products that can cause allergic alveolitis and ODTS. These microorganisms can induce
-aspergillomycosis, bronchial asthma, rhinitis and allergic dermatitis.

The WES does not differentiate between hardwood and softwood dust, although there are some
-questions in some modules investigating whether workers can distinguish with which wood types they
-are working. According to the national experts who supported the European adaptation, workers are
-likely to use both kinds of wood.

\textbf{EU and IARC classification}

Hardwood\textsuperscript{219} dust is listed in the CMD (now CMRD) but not classified according to the EU CLP
-Regulation (because it is a process-generated substance).

Wood dust (including softwood dust) is classified as a Group 1 carcinogen (carcinogenic to humans) by
-the IARC in the monograph from 2012 referenced above. The IARC concluded that there is sufficient
-evidence in humans for the carcinogenicity of wood dust. Wood dust causes cancer of the nasal cavity
-and paranasal sinuses and of the nasopharynx. There is inadequate evidence in experimental animals
-for the carcinogenicity of wood dust.

\textbf{Legislation}

Work involving exposure to hardwood dust has been included for some time in the CMD (now CMRD),
-and a limit value had also been set. Binding OELs for hardwood dust were last amended in 2017 with
-the first amendment to the CMD (now CMRD).\textsuperscript{220} Member States should have brought into force the
-laws, regulations and administrative provisions necessary to comply with this directive by 17 January
-2020. The lower limit value for the inhalable fraction of hardwood dusts has to be applied from 17
-January 2023 onwards. If hardwood dusts are mixed with other wood dusts, the limit value shall apply
-to all wood dusts present in that mixture.


\textsuperscript{219} Hardwoods are produced by angiosperm trees that reproduce by flowers and have broad leaves. As the name suggests, the
-wood from these trees is generally harder than that of softwoods, but there are significant exceptions. In both groups there is an
-enormous variation in actual wood hardness. Softwood is wood from gymnosperm trees such as conifers.

Overview table

<table>
<thead>
<tr>
<th>Substance</th>
<th>Meets the criteria for classification as a category 1A or 1B carcinogen (CLP)</th>
<th>IARC classification</th>
<th>OEL set at EU level/number of the CMRD amendment</th>
<th>Number of workers estimated to be exposed</th>
<th>Production volume per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylamide</td>
<td>X Carc. 1B (may cause cancer)</td>
<td>X Group 2A (probably carcinogenic to humans)</td>
<td>X 1st Amendment Directive 2017/2398</td>
<td>54,000</td>
<td>80,000-150,000 tonnes</td>
</tr>
<tr>
<td>Arsenic (arsenic acid and inorganic compounds)</td>
<td>X Carc. 1A</td>
<td>X Group 1 (carcinogenic to humans)</td>
<td>X 3rd amendment Directive 2019/983</td>
<td>25,300-116,200</td>
<td>n.a.</td>
</tr>
<tr>
<td>Asbestos</td>
<td>X All types classified as Carc. 1A</td>
<td>X All types classified as Group 1 (carcinogenic to humans)</td>
<td>X Asbestos Directive 2009/148/EC (amendment 2023/2668/EU)</td>
<td>4,100,000-7,300,000</td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>X Carc. 1A</td>
<td>X Group 1 (carcinogenic to humans)</td>
<td>X 4th amendment Directive 2022/431</td>
<td>1,012,500</td>
<td>5 million tonnes western Europe (2014); 1,000,000 to 10,000,000 tonnes/year</td>
</tr>
</tbody>
</table>
Criteria for the inclusion of cancer risk factors in the Workers' Exposure Survey on cancer risk factors in Europe

<table>
<thead>
<tr>
<th>Substance</th>
<th>Meets the criteria for classification as a category 1A or 1B carcinogen (CLP)</th>
<th>IARC classification</th>
<th>OEL set at EU level/number of the CMRD amendment</th>
<th>Number of workers estimated to be exposed</th>
<th>Production volume per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,3-Butadiene</td>
<td>X</td>
<td>X Group 1 (carcinogenic to humans)</td>
<td>X 1st Amendment Directive 2017/2398</td>
<td>27,600</td>
<td>2.9 million tonnes</td>
</tr>
<tr>
<td>Cadmium (and compounds)</td>
<td>X</td>
<td>X Cadmium and cadmium compounds Group 1 (carcinogenic to humans)</td>
<td>X 3rd Amendment Directive 2019/983</td>
<td>10,000-300,000</td>
<td></td>
</tr>
<tr>
<td>Chromium(VI) (and compounds)</td>
<td>X Depending on the substance Carc. 1B</td>
<td>X Group 1 (carcinogenic to humans)</td>
<td>X 1st Amendment Directive 2017/2398</td>
<td>917,000</td>
<td></td>
</tr>
<tr>
<td>Cobalt (and compounds)</td>
<td>X Depending on the substance Carc. 1B</td>
<td>X</td>
<td>Planned 6th Amendment to the CMRD</td>
<td>113,000 (67,000-177,000)</td>
<td></td>
</tr>
<tr>
<td>Diesel engine exhaust emissions</td>
<td>Process-generated mixture</td>
<td>X Group 1 (carcinogenic to humans)</td>
<td>X 2nd Amendment Directive 2019/130</td>
<td>3,670,800</td>
<td>Not relevant as process-generated</td>
</tr>
</tbody>
</table>
Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

<table>
<thead>
<tr>
<th>Substance</th>
<th>Meets the criteria for classification as a category 1A or 1B carcinogen (CLP)</th>
<th>IARC classification</th>
<th>OEL set at EU level/number of the CMRD amendment</th>
<th>Number of workers estimated to be exposed</th>
<th>Production volume per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diethyl sulphate/dimethyl sulphate</td>
<td>X</td>
<td>Carc. 1B (probably carcinogenic to humans)</td>
<td></td>
<td></td>
<td>Diethyl sulphate: between 1 and 10 tonnes/year</td>
</tr>
<tr>
<td>Epichlorohydrin</td>
<td>X</td>
<td>Carc. 1B (probably carcinogenic to humans)</td>
<td>X 2nd Amendment Directive 2019/130</td>
<td>43,800</td>
<td>360,000 tonnes</td>
</tr>
<tr>
<td>Ethylene oxide</td>
<td>X</td>
<td>Carc. 1B (carcinogenic to humans)</td>
<td>X 1st Amendment Directive 2017/2398</td>
<td>15,600</td>
<td>3.8 million tonnes</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>X</td>
<td>Carc. 1B (carcinogenic to humans)</td>
<td>X 3rd Amendment Directive 2019/983</td>
<td>990,000-2,200,000</td>
<td></td>
</tr>
<tr>
<td>Lead (and its inorganic compounds)</td>
<td>X</td>
<td>Lead chromate Carc. 1B</td>
<td>X Inorganic lead compounds probably carcinogenic to humans (Group 2A)</td>
<td>X Lead and its inorganic compounds 5th Amendment Directive 2024/869</td>
<td>57,200-148,500</td>
</tr>
</tbody>
</table>
### Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

<table>
<thead>
<tr>
<th>Substance</th>
<th>Meets the criteria for classification as a category 1A or 1B carcinogen (CLP)</th>
<th>IARC classification</th>
<th>OEL set at EU level/number of the CMRD amendment</th>
<th>Number of workers estimated to be exposed</th>
<th>Production volume per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leather dust</td>
<td>X Group 1 (carcinogenic to humans).</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral oils (as mists)</td>
<td>Work involving skin exposure to mineral oils as used engine oils</td>
<td>X Untreated and mildly treated mineral oils are carcinogenic to humans (Group 1)</td>
<td>X No OEL, only skin notation 2nd Amendment Directive 2019/130</td>
<td>1,000,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Nickel (and compounds)</td>
<td>X Nickel compounds Carc. 1A Nickel metal Carc. 2 (suspected to be carcinogenic)</td>
<td>X Nickel compounds Group 1 (carcinogenic to humans) Nickel metal Group 2B</td>
<td>X 4th Amendment Directive 2022/431</td>
<td>87,500</td>
<td>700,000 tonnes</td>
</tr>
<tr>
<td>o-Toluidine</td>
<td>X Carc. 1B</td>
<td>X Group 1 (carcinogenic to humans)</td>
<td>X 1st Amendment Directive 2017/2398</td>
<td>5,500</td>
<td>(likely underestimation) 10,000-100,000 tonnes (one joint registration under REACH)</td>
</tr>
<tr>
<td>Substance</td>
<td>Meets the criteria for classification as a category 1A or 1B carcinogen (CLP)</td>
<td>IARC classification</td>
<td>OEL set at EU level/number of the CMRD amendment</td>
<td>Number of workers estimated to be exposed</td>
<td>Production volume per year</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------------------------------</td>
<td>---------------------</td>
<td>-----------------------------</td>
<td>----------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Silica dust</td>
<td>X</td>
<td>Crystalline silica in the form of quartz or cristoballite dust Group 1 (carcinogenic to humans)</td>
<td>X 1st Amendment Directive 2017/2398</td>
<td>5,300,000 (2006)</td>
<td>Not relevant as it may be both process-generated and manufactured/imported (e.g. quartz sand)</td>
</tr>
<tr>
<td>Respirable crystalline silica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>X Carc. 1B</td>
<td>X Group 1 (carcinogenic to humans)</td>
<td>X 2nd Amendment Directive 2019/130</td>
<td>74,000</td>
<td>More than 10,000 tonnes</td>
</tr>
<tr>
<td>Artificial UVR (including ocular UV)</td>
<td></td>
<td>X Group 1 (carcinogenic to humans)</td>
<td>X Directive 2006/25/EC, exposure limits for non-coherent UVR and coherent UVR (laser)</td>
<td>1.2 million in the EU-27</td>
<td></td>
</tr>
<tr>
<td>Solar UVR (including ocular UV)</td>
<td></td>
<td>X Group 1 (carcinogenic to humans)</td>
<td></td>
<td>36.1 million in the EU-28</td>
<td></td>
</tr>
<tr>
<td>Ionising radiation</td>
<td></td>
<td>X Group 1 (carcinogenic to humans)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substance</td>
<td>Meets the criteria for classification as a category 1A or 1B carcinogen (CLP)</td>
<td>IARC classification</td>
<td>OEL set at EU level/ number of the CMRD amendment</td>
<td>Number of workers estimated to be exposed</td>
<td>Production volume per year</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Wood dust</td>
<td>Process-generated hardwood dust considered as carcinogenic</td>
<td>X Group 1 (carcinogenic to humans)</td>
<td>X Limit value has been included for some time in the CMD (now CMRD) Last amendment of OEL in 1st amendment Directive 2017/2398</td>
<td>Hardwood dust: 3,333,000</td>
<td>Not relevant as it is process-generated</td>
</tr>
</tbody>
</table>
### Job categories (job modules) and tasks (task modules) where the exposure to a given cancer risk factor is assessed

<table>
<thead>
<tr>
<th>Cancer Risk Factor</th>
<th>Job Modules</th>
<th>Task Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INDUSTRIAL CHEMICALS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acrylamide</td>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aMAC Machining Parts</td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td></td>
<td>RUBB_Rubber or plastic Industry</td>
<td></td>
</tr>
<tr>
<td>1,3-butadiene</td>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aBBU Back burning</td>
</tr>
<tr>
<td></td>
<td>FIRE_Firefighter</td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td></td>
</tr>
<tr>
<td></td>
<td>POLI_Police</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RUBB_Rubber or plastic Industry</td>
<td></td>
</tr>
<tr>
<td>Diethyl/dimethyl sulphate</td>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td></td>
</tr>
<tr>
<td>Epichlorohydrin</td>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RUBB_Rubber or plastic Industry</td>
<td></td>
</tr>
<tr>
<td>Ethylene oxide</td>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aCON Container handling</td>
</tr>
<tr>
<td></td>
<td>FOOD_Food Workers</td>
<td>aFUM Fumigation</td>
</tr>
<tr>
<td></td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aMAC Machining Parts</td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td></td>
<td>RUBB_Rubber or plastic Industry</td>
<td>aPES Pesticides for WES</td>
</tr>
<tr>
<td></td>
<td></td>
<td>aSTE Sterilising</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>ARTF_Artist/Film Processing</td>
<td>aCON Container handling</td>
</tr>
<tr>
<td>Cancer Risk Factor</td>
<td>Job Modules</td>
<td>Task Modules</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------</td>
<td>--------------</td>
</tr>
<tr>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aCTW Cutting Wood</td>
<td></td>
</tr>
<tr>
<td>CONS_Construction Trades</td>
<td></td>
<td>aEMB Embalming</td>
</tr>
<tr>
<td>FARM_Farmer</td>
<td></td>
<td>aFAB Fabric Cleaning</td>
</tr>
<tr>
<td>FIRE_Firefighter</td>
<td></td>
<td>aFUM Fumigation</td>
</tr>
<tr>
<td>FLOR_Florist</td>
<td></td>
<td>aGAL Anatomy laboratory</td>
</tr>
<tr>
<td>FOOD_Food Workers</td>
<td></td>
<td>aGLU Glues</td>
</tr>
<tr>
<td>FOUN_Foundry</td>
<td></td>
<td>aMAC Machining Parts</td>
</tr>
<tr>
<td>HAIR_Hairdresser/Beauty Therapist</td>
<td></td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td></td>
<td>aPAI Painting</td>
</tr>
<tr>
<td>LABC_Lab worker Chemist</td>
<td></td>
<td>aPES Pesticides for WES</td>
</tr>
<tr>
<td>LEAT_Leather Tanning</td>
<td></td>
<td>aPTL Pathology laboratory</td>
</tr>
<tr>
<td>MFAC_Metal Finishing &amp; Coating</td>
<td></td>
<td>aSAN Sanding</td>
</tr>
<tr>
<td>POLI_Police</td>
<td></td>
<td>aSTE Sterilising</td>
</tr>
<tr>
<td>PRIN_Printing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUBB_Rubber or plastic Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHOE_Shoes and leather goods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEAC_Teaching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEXT_Textiles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UPHO_Upholstery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ortho-Toluidine</td>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td></td>
</tr>
<tr>
<td>LABC_Lab worker Chemist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUBB_Rubber or plastic Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHOE_Shoes and leather goods</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

<table>
<thead>
<tr>
<th>Cancer Risk Factor</th>
<th>Job Modules</th>
<th>Task Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INORGANIC DUSTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asbestos</td>
<td>FIRE_Firefighter</td>
<td>aASR Asbestos Removal</td>
</tr>
<tr>
<td></td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aDVM Driving/Maintenance</td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td>aFUR Furnace cleaning, installation and maintenance</td>
</tr>
<tr>
<td></td>
<td>LINE_Power Line / Station</td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td></td>
<td>MINE_Miners/Quarrymen</td>
<td>aSER Service tunnels</td>
</tr>
<tr>
<td></td>
<td>WAMA_Waste Management</td>
<td>aSHP Shipping</td>
</tr>
<tr>
<td><strong>Silica</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANIM_Animal Worker</td>
<td></td>
<td>aBED_Animal Bedding</td>
</tr>
<tr>
<td>CERA_Ceramics Glass Prod</td>
<td>aCTS Cutting Stone</td>
<td></td>
</tr>
<tr>
<td>CONS_Construction Trades</td>
<td>aDVM Driving/Maintenance</td>
<td></td>
</tr>
<tr>
<td>DRYC_Dry Cleaner</td>
<td>aFUR Furnace cleaning, installation and maintenance</td>
<td></td>
</tr>
<tr>
<td>FARM_Farmer</td>
<td></td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td>FOOD_Food Workers</td>
<td></td>
<td>aSAN Sanding</td>
</tr>
<tr>
<td>FOUN_Foundry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLTH_Health Workers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LABC_Lab worker Chemist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MFAC_Metal Finishing &amp; Coating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MINE_Miners/Quarrymen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRMM_Metal Refining/Smelting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROAD_RoadConstruction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAMA_Waste Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>METALS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aFUR Furnace cleaning, installation and maintenance</td>
</tr>
</tbody>
</table>
Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

<table>
<thead>
<tr>
<th>Cancer Risk Factor</th>
<th>Job Modules</th>
<th>Task Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>LABC_Lab worker Chemist</td>
<td>aWOP wood preservatives</td>
<td></td>
</tr>
<tr>
<td>LINE_Power Line / Station</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MINE_Miners/Quarrymen</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Cadmium

<table>
<thead>
<tr>
<th>Cancer Risk Factor</th>
<th>Job Modules</th>
<th>Task Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aFUR Furnace cleaning, installation and maintenance</td>
<td></td>
</tr>
<tr>
<td>FOUN_Foundry</td>
<td>aMAC Machining Parts</td>
<td></td>
</tr>
<tr>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aSLD Soldering</td>
<td></td>
</tr>
<tr>
<td>LABC_Lab worker Chemist</td>
<td>aSTP Stripping Paint</td>
<td></td>
</tr>
<tr>
<td>LINE_Power Line / Station</td>
<td>aWEL Welding</td>
<td></td>
</tr>
<tr>
<td>MFAC_Metal Finishing &amp; Coating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRMM_Metal Refining/Smelting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUBB_Rubber or plastic Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEAC_Teaching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAMA_Waste Management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Chromium(VI)

<table>
<thead>
<tr>
<th>Cancer Risk Factor</th>
<th>Job Modules</th>
<th>Task Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARTF_Artist/Film Processing</td>
<td>aART Art ceramic glazes</td>
<td></td>
</tr>
<tr>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aDEG Degreasing</td>
<td></td>
</tr>
<tr>
<td>CONS_Construction Trades</td>
<td>aMAC Machining Parts</td>
<td></td>
</tr>
<tr>
<td>FIRE_Firefighter</td>
<td>aPAI Painting</td>
<td></td>
</tr>
<tr>
<td>FOUN_Foundry</td>
<td>aSTP Stripping Paint</td>
<td></td>
</tr>
<tr>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aWEL Welding</td>
<td></td>
</tr>
<tr>
<td>LABC_Lab worker Chemist</td>
<td>aWOP wood preservatives</td>
<td></td>
</tr>
<tr>
<td>LEAT_Leather Tanning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MFAC_Metal Finishing &amp; Coating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRMM_Metal Refining/Smelting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RUBB_Rubber or plastic Industry</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

<table>
<thead>
<tr>
<th>Cancer Risk Factor</th>
<th>Job Modules</th>
<th>Task Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobalt</td>
<td>TEAC_Teaching</td>
<td>aMAC Machining Parts</td>
</tr>
<tr>
<td></td>
<td>WAMA_Waste Management</td>
<td>aWEL Welding</td>
</tr>
<tr>
<td></td>
<td>CERA_Ceramics Glass Prod</td>
<td>aMAC Machining Parts</td>
</tr>
<tr>
<td></td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aWEL Welding</td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MFAC_Metal Finishing &amp; Coating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MINE_Miners/Quarrymen</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OPET_Oil/Petroleum Industry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PRMM_Metal Refining/Smelting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WAMA_Waste Management</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>AIRT_Air Transport Workers</td>
<td>aART Art ceramic glazes</td>
</tr>
<tr>
<td></td>
<td>CERA_Ceramics Glass Prod</td>
<td>aFUR Furnace cleaning, installation and maintenance</td>
</tr>
<tr>
<td></td>
<td>CONS_Construction Trades</td>
<td>aGUN guns</td>
</tr>
<tr>
<td></td>
<td>FIRE_Firefighter</td>
<td>aMAC Machining Parts</td>
</tr>
<tr>
<td></td>
<td>FOUN_Foundry</td>
<td>aPAI Painting</td>
</tr>
<tr>
<td></td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aSLD Soldering</td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td>aSTP Stripping Paint</td>
</tr>
<tr>
<td></td>
<td>LINE_Power Line / Station</td>
<td>aWEL Welding</td>
</tr>
<tr>
<td></td>
<td>MFAC_Metal Finishing &amp; Coating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MINE_Miners/Quarrymen</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PRIN_Printing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PRMM_Metal Refining/Smelting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ROAD_RoadConstruction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RUBB_Rubber or plastic Industry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WAMA_Waste Management</td>
<td></td>
</tr>
<tr>
<td>Cancer Risk Factor</td>
<td>Job Modules</td>
<td>Task Modules</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Nickel</td>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aART_Art ceramic glazes</td>
</tr>
<tr>
<td></td>
<td>FOUN_Foundry</td>
<td>aMAC_Machining Parts</td>
</tr>
<tr>
<td></td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aSAN_Sanding</td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td>aSTP_Stripping Paint</td>
</tr>
<tr>
<td></td>
<td>MFAC_Metal Finishing &amp; Coating</td>
<td>aWEL_Welding</td>
</tr>
<tr>
<td></td>
<td>MINE_Miners/Quarrymen</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OPET_Oil/Petroleum Industry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PRMM_Metal Refining/Smelting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEAC_Teaching</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WAMA_Waste Management</td>
<td></td>
</tr>
</tbody>
</table>

**OILS**

<table>
<thead>
<tr>
<th>Cancer Risk Factor</th>
<th>Job Modules</th>
<th>Task Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oils</td>
<td>AIRT_Air Transport Workers</td>
<td>aCTO_Cutting Oils</td>
</tr>
<tr>
<td></td>
<td>FORE_ForestryTimbermill</td>
<td>aSHP_Shipping</td>
</tr>
<tr>
<td></td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OPET_Oil/Petroleum Industry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PRIN_Printing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PRMM_Metal Refining/Smelting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEXT_Textiles</td>
<td></td>
</tr>
</tbody>
</table>

**ORGANIC DUST**

<table>
<thead>
<tr>
<th>Cancer Risk Factor</th>
<th>Job Modules</th>
<th>Task Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leather dust</td>
<td>LEAT_Leather Tanning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHOE_Shoes and leather goods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UPHO_Upholstery</td>
<td></td>
</tr>
<tr>
<td>Wood dust</td>
<td>CLNR_Cleaner</td>
<td>aBED_Animal Bedding</td>
</tr>
<tr>
<td></td>
<td>CONS_Construction Trades</td>
<td>aCTW_Cutting Wood</td>
</tr>
</tbody>
</table>
### Criteria for the inclusion of cancer risk factors in the Workers’ Exposure Survey on cancer risk factors in Europe

<table>
<thead>
<tr>
<th>Cancer Risk Factor</th>
<th>Job Modules</th>
<th>Task Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel engine exhaust emissions</td>
<td>MINE_Miners/Quarrymen</td>
<td>aDVM Driving/Maintenance</td>
</tr>
<tr>
<td></td>
<td>PESA_Petrol Station Attendant</td>
<td>aFPE Fuel-powered equipment</td>
</tr>
<tr>
<td></td>
<td>RAIL_Railway</td>
<td>aGEX Generator Exhaust</td>
</tr>
<tr>
<td></td>
<td>ROAD_RoadConstruction</td>
<td>aSHP Shipping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>aVEX Vehicle Exhausts</td>
</tr>
<tr>
<td>PRODUCTS OF COMBUSTION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RADIATION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial UV radiation (* including ocular exposure)</td>
<td>HAIR_Hairdresser/Beauty Therapist*</td>
<td>aAUV_Artificial UV*</td>
</tr>
<tr>
<td></td>
<td>HLTH_Health Workers*</td>
<td>aPAI Painting</td>
</tr>
<tr>
<td></td>
<td>MFAC_Metal Finishing &amp; Coating*</td>
<td>aSTE Sterilising</td>
</tr>
<tr>
<td></td>
<td>WELD_Welder*</td>
<td>aWEL Welding*</td>
</tr>
<tr>
<td>Ionising radiation</td>
<td>AIRT_Air Transport Workers</td>
<td>aENU Nuclear energy &amp; waste</td>
</tr>
<tr>
<td></td>
<td>CLNR_Cleaner</td>
<td>aFFL Frequent Flyer</td>
</tr>
<tr>
<td></td>
<td>FOOD_Food Workers</td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td></td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aMXR Medical radiation</td>
</tr>
<tr>
<td></td>
<td>MINE_Miners/Quarrymen</td>
<td>aSTE Sterilising</td>
</tr>
<tr>
<td></td>
<td>POLI_Police</td>
<td>aXRY Xray use</td>
</tr>
<tr>
<td>Solar UV radiation (including ocular exposure)</td>
<td></td>
<td>aUVR Solar UV</td>
</tr>
<tr>
<td>Cancer Risk Factor</td>
<td>Job Modules</td>
<td>Task Modules</td>
</tr>
<tr>
<td>--------------------</td>
<td>------------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td><strong>SOLVENTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>AIRT_Air Transport Workers</td>
<td>aBBU Back Burnig</td>
</tr>
<tr>
<td></td>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aCLH Cleaning Hands</td>
</tr>
<tr>
<td></td>
<td>DRYC_Dry Cleaner</td>
<td>aCON Container handling</td>
</tr>
<tr>
<td></td>
<td>FIRE_Firefighter</td>
<td>aDEG Degreasing</td>
</tr>
<tr>
<td></td>
<td>FOUN_Foundry</td>
<td>aDVM Driving/Maintenance</td>
</tr>
<tr>
<td></td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td>aFAB Fabric Cleaning</td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td>aFPE Fuel-powered equipment</td>
</tr>
<tr>
<td></td>
<td>LINE_Power Line / Station</td>
<td>aFTC Fuel tank cleaning</td>
</tr>
<tr>
<td></td>
<td>MFAC_Metal Finishing &amp; Coating</td>
<td>aGEX Generator Exhaust</td>
</tr>
<tr>
<td></td>
<td>OPET_Oil/Petroleum Industry</td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td></td>
<td>PESA_Petrol Station Attendant</td>
<td>aPAI Painting</td>
</tr>
<tr>
<td></td>
<td>POLI_Police</td>
<td>aPES Pesticides for WES</td>
</tr>
<tr>
<td></td>
<td>PRIN_Printing</td>
<td>aSHP Shipping</td>
</tr>
<tr>
<td></td>
<td>ROAD_RoadConstruction</td>
<td>aVEX Vehicle Exhausts</td>
</tr>
<tr>
<td></td>
<td>RUBB_Rubber or plastic Industry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEXT_Textiles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UPHO_Upholstery</td>
<td></td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>CHEM_Chemical Pharmaceutical Manufacturing</td>
<td>aDEG Degreasing</td>
</tr>
<tr>
<td></td>
<td>DRYC_Dry Cleaner</td>
<td>aMAH Material Handling</td>
</tr>
<tr>
<td></td>
<td>IMAR_Industrial Manufacturing, Assembly and repair</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LABC_Lab worker Chemist</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHOE_Shoes and leather goods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEAC_Teaching</td>
<td></td>
</tr>
</tbody>
</table>