European Agency for Safety and Health at Work

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Exposure to carcinogens and work-related cancer: A review of assessment methods

European Risk Observatory
Executive Summary

European Agency for Safety and Health at Work

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1. Introduction

Occupational cancer is a problem that needs to be tackled across the European Union (EU). Estimates of the recent and future burden of occupational diseases indicate that occupational cancer is still a problem and will remain so in the future as a result of exposure of workers to carcinogens.

The goals to which this review aims to contribute are to:

- describe occupational exposure to carcinogens and cancer-causing or -promoting working conditions at European, national and workplace levels;
- evaluate existing sources of information, identify major knowledge gaps and describe some new approaches needed to assess and prevent occupational cancer risks;
- describe occupational cancer prevention measures at European, national and workplace levels; and
- make some recommendations for filling in gaps in relevant knowledge needed to prevent effectively future risks of occupational cancer.

The report looks into relevant occupational factors: chemical, physical and biological exposures, as well as other possibly carcinogenic working environment conditions (such as shift and night work). It also examines opportunities to identify new causes or promoters of cancer.

The issue of vulnerable groups of workers (for example women, young workers, workers experiencing high exposure to carcinogens, workers in precarious conditions) is addressed.

Less attention will be paid to topics that have been reviewed in detail elsewhere, such as the burden of disease, recognition of and compensation for occupational cancers (which are covered in statistical data collection by Eurostat through the European Occupational Disease Statistics), and the working capacity of cancer patients (although reference is made to some reports on return to work).

The target groups the report is aimed at are occupational safety and health (OSH) researchers and policy-makers, including social partners. It may also be useful to OSH prevention stakeholders for priority setting, and to those who deal with workplace risk assessment.

2. Risk factors for cancer and occupational exposure to carcinogens

Risk factors

Chemical substances and radiation are well-known causes of occupational cancer. Only a relatively small number of cancer-causing chemical exposures have been investigated thoroughly, and a lot remains to be done about other risks, such as physical, pharmaceutical and biological factors.

Shift work that involves circadian disruption and sedentary work have recently been identified as possible contributing factors to the development of work-related cancer and there is increasing evidence that specific non-ionising radiation could be linked to cancer risks. Work-related stress may indirectly lead to cancers, as workers may employ coping strategies that involve smoking, drinking, drug consumption or excessive, unbalanced eating. There are also emerging risks from nanomaterials, for example carbon nanotubes, and from endocrine-disrupting compounds, which are discussed in the report.

Cancer-causing factors and working conditions may be classified as carcinogenic by scientists and by scientific panels, but the knowledge gained from research needs to be translated into prevention measures and legal requirements by regulators, which can be a very slow process.

Furthermore, occupational exposure is rarely about a single factor; rather, it involves a combination of factors. This needs greater attention.

Scientists agree that the current understanding of the relationship between occupational exposures and cancer is far from complete. Only a limited number of individual factors are established occupational carcinogens. For many more, no definitive evidence is available based on exposed workers. However, in many cases, there is considerable evidence of increased risks associated with particular industries and occupations, although often no specific agents can be identified as aetiological factors. However, legislation often requires clearly defined factors (Boffetta *et al*., 2003).

An overview of cancer risk factors relevant to workers is given in Table 1.

Table 1: Overview of OSH-relevant carcinogenic factors

Group	Example
Chemicals	
Gases	Vinyl chloride Formaldehyde
Liquids, volatile	Trichloroethylene Tetrachloroethylene Methylchloride Styrene Benzene Xylene
Liquids, non-volatile	Metalworking fluids Mineral oils Hair dyes
Solids, dust	Silica Wood dust Talc containing asbestiform fibres
Solids, fibres	Asbestos Man-made mineral fibres, for example ceramic fibres
Solids	Lead Nickel compounds Chromium VI compounds Arsenic Beryllium Cadmium Carbon black Bitumen
Fumes, smoke	Welding fumes Diesel emissions Coal tar fumes Bitumen fumes Fire, combustion emissions PAHs Tobacco smoke

Group	**Example**
Mixtures	Solvents
Pesticides	
Halogenated organic compounds	DDT Ethylene dibromide
Others	Amitrole
Pharmaceuticals	
Antineoplastic drugs	MOPP (Mustargen, oncovin, procarbazine and prednisone, a combination chemotherapy regimen used to treat Hodgkin's disease) and other combined chemotherapy, including alkylating agents
Anaesthetics	There is evidence from *in vitro* experiments that isoflurane increases cancer cells' potential to grow and migrate (Barford, 2013; McCausland, Martin & Missair, 2014)
Emerging factors	
Air pollution and fine particulate matter	Emissions from motor vehicles, industrial processes, power generation, and other sources polluting the ambient air (IARC, 2014)
Endocrine-disrupting compounds	Certain pesticides Certain flame retardants
Biological factors	
Bacteria	Helicobacter pylori
Viruses	Hepatitis B Hepatitis C
Mycotoxin-producing fungi	Bulk handling of agricultural foodstuffs (nuts, grain, maize, coffee), animal-feed production, brewing/malting, waste management, composting, food production, working with indoor moulds, horticulture
Aspergillus flavus, *A. parasiticus*	Aflatoxin (A1)
Penicillium griseofulvum	Griseofulvin (IARC group 2B)
A. ochraceus, *A. carbonarius*, *P. verrucosum*	Ochratoxin A (group 2B)
A. versicolor, *Emericella nidulans*, *Chaetomium spp.*, *A. flavus*, *A. parasiticus*	Sterigmatocystin (group 2B)
Fusarium spp.	Fumonisin B1 (group 2B)
Physical factors	
Ionising radiation	Radon X-rays
Ultraviolet radiation (UVR)	Solar radiation Artificial UVR

Group	Example
Ergonomics	Sedentary work
Other	
Work organisation	Shift work that involves circadian disruption Static work Prolonged sitting and standing
Lifestyle factors	Stress-related obesity, smoking, drinking, drug consumption
Combinations of various factors	
Chemicals and radiation	Methoxsalen and UVA radiation Some chemicals, called 'promoters', can increase the cancer-causing ability of UVR. Conversely, UVR can act as a promoter and increase the cancer-causing ability of some chemicals, in particular in coal tar and pitch (CCOHS, 2012).
Work organisation and chemicals	Shift work and solvents

Source: compiled by the authors, adapted from Clapp, Jacobs & Loechler, 2007; Siemiatycki *et al.*, 2004; EU-OSHA, 2012; Boffetta *et al.*, 2003; BAuA, 2007; Heederik, 2007; IARC, 2012; and BAuA, 2014a

3. Sources of data on occupational exposure to carcinogens

There are three types of data sources that provide information about occupational exposure to carcinogens: a) national registers, b) exposure measurement databases and c) exposure information systems.

a) National registers

Some countries have established national registers on exposures to selected carcinogens, which provide data on the numbers of exposed workers and their exposures. These registers include the Finnish Register of Workers Exposed to Carcinogens (ASA Register), the Italian Information System for Recording Occupational Exposures to Carcinogens (SIREP) and the German ODIN Register, which collects information on workers who have been exposed to certain categories of carcinogens and are entitled to medical examinations because of their carcinogen exposure. Sources from other countries, such as Poland, Slovakia and the Czech Republic, are difficult to access for professionals from other countries because of language issues. It is common to all these systems that they usually provide information on a pre-set selection of suspected or proven carcinogens, often factors or substances about which a certain amount of information already exists.

National registers monitoring exposures to chemical carcinogens are more developed in some countries. However, they do not cover even nearly all relevant carcinogens and underreporting is very likely. In particular, occasional and low exposures tend to be underreported to these official registers. However, these registers identify workplaces where certain carcinogens are being used, and to some extent they may encourage preventive measures to be taken, and they may also help the labour safety authorities to focus their inspection, guidance and control activities. There is suggestive evidence that registration increases awareness and preventive measures in workplaces that have to notify exposed workers (Kauppinen *et al.*, 2007). The danger is that providing notifications becomes only an annual routine that does not result in any measures reducing carcinogen exposures and risks in workplaces. This is a concern especially in relation to young workers, who are often contracted on temporary and short-term contracts or in occasional tasks such as maintenance tasks, while at the same time carrying out work exposing them to several cancer risk factors.

Many of the chemical exposures identified are generated at work and are not covered by REACH, the EU regulation on the registration, evaluation, authorisation and restriction of chemicals (such as diesel exhaust, welding fumes, silica, endotoxins, and so on). However, for those single carcinogenic substances that do come under REACH legislation (being either registered or included in the list of substances of very high concern), use conditions and preventive measures required will be determined in the exposure scenarios included in the extended safety data sheets (SDSs) of the regulated substances. This information on the safe use of carcinogens should also be forwarded to downstream users, who, in turn, may promote and improve prevention.

b) Exposure measurement databases

Concentrations of many chemical carcinogens have also been measured in workroom air. Data on the results of industrial hygiene measurements have been computerised in many countries. Some of these sources cover not only chemical carcinogens but also non-chemical carcinogens or suspected carcinogens (such as ionising or ultraviolet radiation, electromagnetic fields or night work). Some examples are presented in the report, such as the MEGA database in Germany, the international ExpoSYN database, which covers five respiratory carcinogens and data from 19 countries, including Canada, and COLCHIC and SCOLA from France. The national databases all have in common that access to data is restricted for confidentiality reasons and data are available only in the national language.

Data in these databases are potentially useful for prevention, and better reporting of high-exposure situations and dissemination of information on them is desirable. In the report, the Finnish 'Dirty dozen' project is presented; it aims to integrate the identification, assessment and prevention of the most serious risks due to occupational exposure to carcinogens and other harmful chemical agents. As another example, a trend study based on the Finnish Information System on Occupational Exposure (the Finnish Job–Exposure Matrix, or FINJEM) is described. Trend analyses of chemical exposure may serve several purposes, such as hazard surveillance, quantitative risk assessment, exposure assessment in occupational epidemiology, setting of priorities for preventive measures, and the prediction of future risks. The effective prevention of future work-related diseases due to chemical exposure requires knowledge of exposure trends.

c) Exposure information systems

There are international and national exposure information systems about carcinogens that are not based on notifications of exposed workers or workplaces or on workplace measurements but instead rely on estimations of the numbers of exposed workers and their level of exposure to selected carcinogens: the International Information System on Occupational Exposure to Carcinogens (CAREX) was set up in the mid-1990s and includes estimates of exposure prevalence and numbers of exposed workers in 55 industries for 15 Member States of the EU between 1990 and 1993 (Kauppinen *et al*., 2000). The major use of CAREX has been in hazard surveillance and risk/burden assessment. It has been updated in Finland (CAREX Finland, updated with exposure level estimates, reported only in Finnish), Italy (Mirabelli & Kauppinen, 2005) and Spain. New countries have been added to CAREX (Estonia, Latvia, Lithuania, the Czech Republic) (Kauppinen *et al*., 2001) and it has been applied to Costa Rica, Panama and Nicaragua (in these countries, CAREX includes data on pesticides) (Partanen *et al*., 2003, Blanco-Romero *et al*., 2011). It has been modified for wood dust (WOODEX), with exposure level estimates for 25 EU Member States (Kauppinen *et al*., 2006). CAREX has been used in the assessment of the global burden of work-related cancers by WHO (Driscoll *et al*., 2005) and to assess the burden of occupational cancer in the United Kingdom (Rushton *et al*., 2008) and other EU Member States. The SHEcan project financed by the European Commission, for example, used information on exposures to support prioritisation of substances for setting occupational exposure limits (OELs) and to support building the evidence base for individual substance assessment.

Other exposure information systems covering chemical agents also include estimates of the numbers of exposed workers and information on carcinogens. The report presents several examples, one of which is the FINJEM, which covers a large selection of exposures, including carcinogens. FINJEM has also been useful for setting up other national job—exposure matrices (JEMs), for example those in Sweden, Norway, Denmark and Iceland, which were used in the Nordic Occupational Cancer Study (NOCCA).

Information on carcinogen exposure is also contained in the French SUMER survey (the Medical Monitoring Survey of Professional Risks), conducted in 1994, 2003 and 2010, which was validated by using national exposure data from COLCHIC. The COLCHIC database consolidates all data on occupational exposure to chemicals collected from French companies by the regional health insurance funds (Caisses Régionales d'Assurance Maladie, CRAM) and the national institute for research and safety (Institut National de Recherche et de Sécurité, INRS).

Some of these sources also provide information on non-chemical factors, for example on shift work, solar radiation and radon. An overview is provided in Table 2.

4. Occupational exposure to carcinogens

The report presents in detail data from the sources described above, providing information on the numbers of exposed workers, the various substances or factors, exposure levels, sectors, and so on.

However, the exposure information from various countries presented in the report cannot be regarded as an overview. Information on the extent of exposure to carcinogenic agents and factors in Europe is worryingly out of date. The most comprehensive effort so far has been the CAREX project, which addressed occupational exposure to carcinogens in 15 (subsequently extended to 19) Member States of the EU more than 20 years ago (in 1990–93) (Kauppinen *et al*., 2000). According to the CAREX data, exposure to carcinogens at work is common, with the number of workers estimated as being exposed in the early 1990s exceeding 30 million, which is over 20 % of the entire workforce.

The most common exposures were ultraviolet radiation in sunlight (during regular outdoor work) and environmental tobacco smoke (ETS) (in restaurants and other workplaces), and ETS and UVR accounted for about half of all exposures.

Since the early 1990s, exposure to ETS at work has been substantially reduced as a result of prohibitions and other restrictions. Other relatively commonly occurring exposures that are likely to have decreased include lead, ethylene dibromide (an additive used in leaded petrol), asbestos and benzene.

From the point of view of preventing occupational cancers, it is important to gather knowledge on the levels of exposure in different occupations, jobs and tasks. For example, information systems such as CAREX would be more useful as systems for hazard surveillance, quantitative risk and burden assessment, and setting of priorities for prevention if they incorporated estimates of levels of exposure among the individuals exposed.

Other useful improvements to CAREX, in addition to the updating of outdated information, might be extension to important non-carcinogens, inclusion of a time dimension, inclusion and better use of exposure measurement data in estimations, extension to all Member States of the EU, inclusion of gender-specific and occupation-specific estimates, and inclusion of uncertainty information on the estimates. One or several of these improvements have been adopted in some other exposure information systems, such as WOODEX, TICAREX, Matgéné, FINJEM and CAREX Canada, which has incorporated most of these features, and in addition disseminates information of exposures and risks through an informative, easy-to-use and free-of-charge web application.

The most highly developed model at the moment is probably CAREX Canada, which has incorporated most of these features, and in addition disseminates information on exposures and risks through an informative, easy-to-use and free-of-charge web application. The methods of assessment and the definitions of exposure classes are clearly reported in a dedicated website, which includes training videos and tutorials, as well as a risk assessment tool (eRisk) for environmental exposures. The occupational exposure tool (eWork) shows data by carcinogen, region, industry, occupation, gender and level of exposure.

Table 2 lists sources that include information about occupational exposure to carcinogens in worker groups that may be at higher than average risk of contracting occupational cancer as a result of their personal characteristics or higher than average exposure to carcinogens, for example pregnant women and young workers.

Table 2: Sources of exposure information on non-chemical carcinogenic factors and on vulnerable workers

Factor/group	Sources of information	Remarks
Non-chemical factor		
UVR or solar radiation	CAREX, CAREX Canada, TICAREX, NOCCA-JEMs, FINJEM	Artificial UV and solar radiation are treated separately in CAREX Canada
Ionising radiation or radon	CAREX, CAREX Canada, FINJEM	Radon and ionising radiation are treated separately in CAREX
Electromagnetic fields	Electromagnetic field JEMs, FINJEM	See Bowman, Touchstone & Yost, 2007; Koeman *et al.*, 2013
Hepatitis viruses	–	Some data on the numbers of occupational diseases caused by hepatitis are available (Eurostat and national registers of occupational diseases)
Shift work, including night shift work	EWCS, CAREX Canada, national surveys	For EWCS data, see Eurofound website
Vulnerable groups		
Women	CAREX Canada, TICAREX, Matgéné, SUMER, ASA,	
Young workers	SUMER	Age group < 25 years
Workers with high levels of exposure and possibly at high risk	CAREX Canada, FINJEM, Matgéné, SUMER, WOODEX, measurement databases such as MEGA and COLCHIC.	The definition of 'high' varies by source

EWCS, European Working Conditions Surveys

Source: Overview by the authors

The effective prevention of work-related diseases requires knowledge of exposure trends. The current burden of occupational cancer and other chronic diseases attributable to chemical exposure has often been estimated on the basis of epidemiological studies and past exposure. From the point of view of prevention, it would be beneficial to estimate the future impact of present exposure. This would require information on the numbers of exposed workers and their levels of exposure over time. Quantitative estimates of these are not usually available, but can be derived in selected cases by using job–exposure matrices (JEMs). Examples described in this report are the burden assessments carried out in the UK and the Finnish exposure trend analyses.

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Additionally, the estimates of CAREX and other similar information systems have not been validated using other methods of estimation or measurement. In fact, validation is not even feasible because of the very large number of estimates and the lack of reliable alternative data. The re-evaluation of the estimates of CAREX in the UK using another approach (another dataset and different experts) suggested that the original CAREX estimates were mainly on the high side, although in some cases underestimation was also possible (Cherrie, van Tongeren & Semple, 2007). FINJEM estimates have been compared with those derived from a Canadian dataset from the region of greater Montreal (Lavoué *et al*., 2012). The comparison proved methodologically difficult. The sources of disagreement included the actual exposure differences between Finland and the Montreal region, the conversion of occupational classifications, the different exposure metrics used by FINJEM and the Montreal dataset, differences in the inclusion of low exposures (minimum criteria) and different ways of using available data. Although the disagreements may be partly explained by actual differences in the levels of exposure and methodological problems inherent in the comparison, it is also likely that the knowledge and interpretations of the assessors contributed to the disagreements. Since the actual (true) exposures are unknown, comparisons of JEMs probably reveal only the transportability of JEMs to deal with exposures in another region and population, rather than their validity. The final validity of estimates in all comprehensive exposure information systems therefore tends to remain unknown. There is evidence that the transportability of estimates between countries is limited, and therefore the direct application of estimates made in one country to some other country can provide only a crude initial approximation of exposure. Validating the most relevant estimates (for example, estimates indicating high exposure and exposures in major industries or occupations) would increase the credibility of the overall results.

It is also worth noting that many of the estimates in CAREX and other exposure matrices are based on ‘expert judgement’. Empirical data on the prevalence and level of exposure are used only if readily available. Even when measurement data is available, assessing its representativeness and applicability to the occupations or industries requires expert judgement and that introduces a subjective element into the estimates. The validity of exposure estimates is likely to increase in the future when more measurement data from different sources becomes available in computerised form and the so-called ‘Bayesian’ methods of combining measurement data and expert judgements (prior views of experts) become more widely used.

5. Conventional and new approaches to the assessment and prevention of occupational cancer

The Nordic occupational cancer study (NOCCA) is a very large cohort study based on the follow-up of the whole working populations in one or more censuses in Denmark, Finland, Iceland, Norway and Sweden. The total number of workers in the follow-up is 15 million and the number of cancer cases diagnosed after the earliest census was 2.8 million. Census data in the Nordic countries include occupation for each employed person at the time of the census (every 5 to 10 years), as coded according to national classifications. Cancer data are available from national cancer registers. NOCCA aims to identify occupations and aetiological factors associated with cancer risks. Standardised incidence ratios have been calculated for 54 occupational categories with regard to over 70 different cancers or histological subtypes of cancer (Pukkala *et al.*, 2009). The comprehensive data from NOCCA to analyse cancer risks by occupation and by occupational exposure should be fully utilised to focus prevention and prioritise research in specific areas.

Surveillance systems for occupational cancer are helpful for assessing national and regional risks, and they improve identification of suspected cases of occupational cancer, as well as being useful in the legal compensation process. Examples of such systems are the French Scientific Interest Group on Occupational Cancer (GISCOP), which incorporates a retrospective exposure history assessment for workers affected by cancer through interviews and social security and employment data, and the Italian Occupational Cancer Monitoring (OCCAM) project, which actively seeks information on victims of occupational cancer by following up on high-exposure histories of workers.

Asbestos removal work after a fire

6. Policies and strategies

A comprehensive regulatory framework has been designed to protect workers from exposure to chemical carcinogens. According to the International Labour Organisation (ILO) conventions and recommendations, governments are required to:

- frequently determine carcinogenic agents/factors (not restricted to chemicals and including factors that develop in the course of work processes), whereby the latest findings have to be used;
- make every effort to replace carcinogenic agents/factors with harmless or less harmful ones;
- generally prohibit work under exposure to such factors, although exceptions may be granted as specified below;
- grant exceptions only under very strict conditions, including:
- the issuing of a certificate specifying in each case the protection measures to be applied,
- medical supervision or other tests or investigations to be carried out,
- records to be maintained, and
- professional qualifications required of those dealing with the supervision of exposure to the substance or agent in question;
- implement tight medical supervision, including after cessation of the worker's assignment; and
- where appropriate, specify levels as indicators for surveillance of the working environment in connection with the technical preventive measures required.

Similar principles are laid down in the relevant European directives, with a particular emphasis on the hierarchy of control measures that places elimination and substitution at the top of the priority scale, and on extensive documentation obligations. However, the authors noted that the EU legislation falls short of the ILO requirements by prohibiting work under the exposure of carcinogenic factors in a few cases only, and by demanding records only 'when requested' by the competent authority (Carcinogens and

Mutagens Directive, Article 6) (EC, 2004). According to trade union sources, records are rarely requested and therefore may not be kept by employers. These records could be a sound foundation for extensive exposure databases. This applies to chemicals, and the situation is considered worse with regard to other potential risk factors.

Furthermore, not all EU countries have followed the ILO recommendation to establish compulsory notification of workers exposed to carcinogens. It is advisable to set up a comprehensive national register for all countries, enabling Europe-wide data collection on carcinogen exposure. In future, these registers should also cover all relevant carcinogens, and the current problems of underreporting should be solved.

For substances for which no safe threshold can be established, many countries have an obligation to make every effort to reduce concentrations to the lowest possible level, if the substances cannot be eliminated. Other countries are developing exposure limits based on the concept of tolerable/acceptable risk, usually in the range of 10^{-2} to 10^{-5} cases of cancer, depending on whether the risks concern the frequency of changes in health status during a year or over a lifetime. This corresponds to an average risk of sustaining a fatal accident. Based on this concept, Germany has developed an approach consisting of three risk bands and a tiered control scheme, aimed at stimulating minimisation efforts in companies (Wriedt, 2012; Bender, 2012).

Similar general principles apply to all the other risks identified in this report. However, they have not been translated into more specific regulations and there is a lack of knowledge on how to tackle these risks at workplace level.

While in European Member States the compensation of workers is often a very slow process with high hurdles, in Denmark factors recognised by the International Agency for Research on Cancer (IARC) (groups 1 and 2a) are added with little delay to the occupational diseases list. Decisions by commissions on compensation claims need not to be unanimous. Thus, hurdles to compensation claims are considerably lower than in other Member States (Melzer, 2014).

The report presents a selection of different national actions taken to address the issue of work-related cancer. While not being exhaustive, it is intended to give an insight into the range of approaches chosen to tackle the issues and promote prevention. Common to all these approaches is that many actions are carried out at the sectoral level and that they need broad stakeholder involvement to be successful. This section of the report also describes national strategies that are integrated with other policy areas such as environmental protection and public health.

7. Conclusions and recommendations

7.1. Conclusions

Exposure

According to the goals of European OSH legislation, policy-makers have to ensure that occupational cancer risks are identified and that exposure to these factors is prohibited. Where exceptions may be granted, strict conditions must be set, including proof of effective protection for each case and safeguarding medical supervision. This still remains a big challenge, as outlined in the report. Awareness of occupational cancer risks is still not sufficiently developed, considering the numerous factors that may cause the disease and the high degree of associated suffering. Awareness and knowledge are considered very low for physical and biological factors.

On the whole, the information on occupational exposure to carcinogens in Europe is outdated and incomplete. Yet occupational exposure data are the basis for assessing risks, the burdens of diseases and other consequences of exposure, identifying high-risk worker groups and setting prevention priorities. The CAREX estimates from the early 1990s should be updated.

The CAREX update should be seen as a priority task, likely to promote the assessment and effective prevention of work-related cancer in Europe. The following steps should be taken to foster analysis of the data: incorporate exposure level estimates, include information by gender, assess uncertainty of the estimates, and include all EU countries and all relevant carcinogenic exposures (and possibly other chemical agents of high concern) in the update. Trend information on exposures should also be incorporated, if feasible. A clear definition of scope and resources is needed.

Information exchange on exposure data at national level could improve the knowledge base, for example regarding the proportion of those exposed and the duration and intensity of exposure. National cancer registers, disease registers, and data on cancers reported via compensation and insurance schemes can provide a valuable insight into the distribution of diseases and the most prevalent diseases in specific occupations if they are combined with employment data and data from social security registers.

There are also new and emerging risks for stakeholders to consider, and these include nanomaterials (for example carbon nanotubes), some of which have recently been categorised by IARC as carcinogens, endocrine-disrupting compounds and non-ionising radiation, as well as stress (through coping strategies such as smoking, drugs, and so on). Shift work that involves circadian disruption and sedentary work have been identified as potential contributing factors to the onset of work-related cancer, but they have hardly received the attention they warrant, in relation neither to exposure assessment nor to prevention. Additionally, there has not been sufficient study of the effects of new working forms on carcinogen exposure (or on exposure overall). Careers are set to become more fragmented and variable, and work may be done in many locations and at irregular times, which will also change the exposure patterns of future workers.

More consideration to be given to vulnerable groups

Vulnerable groups include women, young workers and workers with high levels of exposure. It has been argued that some groups can be considered as ‘inherently’ vulnerable, the ‘particularly sensitive risk groups’ (for example ageing workers, young workers, female workers), while in the case of workers with high levels of exposure their vulnerability can be attributed to the job itself (and possibly to the fact that in the sector in question the high level of exposure is a result of the fact that OSH regulations are not respected). However, there is an overlap between these groups, and the different conditions may interact. Consequently, the differences in metabolism, pre-existing health problems — including those caused by work, such as respiratory disorders — the norms of the sector, its safety culture and employment conditions, and the specific conditions of the workplace need to be considered when identifying vulnerable groups through workplace risk assessment, epidemiology or exposure measurements.

Worker groups exposed to high levels of carcinogens may be considered vulnerable. Information systems that include levels of exposure are partially able to identify those worker groups requiring special attention. In particular, exposure measurement databases include valuable information on jobs and tasks where exposure may be high, but this information is frequently confidential. An enterprise where a high exposure has been identified may take direct action to reduce exposure. Information on this could be very valuable for similar enterprises and for labour inspectors operating in the sector. The dissemination of information through the internet, the media or inspectors may encourage enterprises to assess and measure their own exposure levels and subsequently reduce them, if they are found to be high. Sharing of information on high exposures is still limited, because the data of many measurement databases are not publicly available, for confidentiality reasons.

The available data seem to indicate that women are in most cases less frequently exposed to carcinogens than men. There are some exceptions, and the numbers of women reported to be exposed to carcinogenic substances (including pregnant women) is still substantial. However, exposure information is mostly based on occupations with a majority of male workers and data, for example on exposure to diesel exhaust, are rarely available by gender and seldom collected in a gender-sensitive way, by considering equally sectors where men and women work and their typical exposures. Because awareness is low and occupational history poorly monitored and described, underrecognition of female work-related cancers is likely to happen, according to some studies. Women may be more susceptible to certain factors because of differences in metabolism. However, most studies on health effects are based on male workers (EU-OSHA, 2013).

Some of the most common exposures experienced by women in the CAREX studies that addressed gender were diesel engine exhaust, solar radiation and ETS, which are poorly covered by registers, although they are very relevant to a wide range of occupations and sectors.

Young worker exposed to wood dust

According to the limited data available from the data sources described in this report, female workers are more affected than male workers by factors such as formaldehyde, cytostatic drugs, biocides, hair dyes and some biological agents. These exposures are particularly relevant to service workers and professions where the majority of workers are women, like the health-care sector, cleaning, hairdressing and the textile industry. Exposures to biological agents in the food processing industry or in waste management and recycling may severely affect female workers, but there is very patterns and levels of exposure. In addition, in many countries, a high proportion of women work in part-time jobs, and their exposures may go unreported and therefore not be considered when setting measures for prevention. With an increasing number of women moving into non-traditional jobs, for example in construction and transport, and restructuring leading to a higher proportion of women in some sectors, such as agriculture, exposure patterns have changed. As an example, in Denmark, nowadays, one-third of house painters are female.

Young workers may be considered vulnerable because they may have a very long exposure time during their life and because their biological development may make them more sensitive to the toxic effects of chemical agents. Additionally, according to the French SUMER survey, young workers are more exposed to carcinogenic factors than other workers. Workers doing maintenance tasks are particularly at risk of exposure to the carcinogenic agents evaluated in that survey, especially young workers in apprenticeships and subcontracted workers.

In addition, they are more likely to have multiple exposures. According to EU-OSHA research, young workers are also the group with the highest proportion of temporary contracts, and they frequently work on a part-time basis and at irregular hours, which limits their access to preventive services. They are often employed in the hospitality sector and in low-qualified jobs. Before the prohibition of smoking in many EU countries, young workers were also particularly exposed to tobacco smoke in the hospitality sector.

Unfortunately, age-specific data on carcinogen exposure is also scarce, and little is known on exposure prevalence and exposure patterns and levels for workers of different ages. They may depend on a variety of factors, for example on the carcinogen in question and the cultural norms and the industrial structure of the country, as well as on the contractual arrangements and employment patterns in different occupations and different age groups, and differences in conditions for women and men.

Other emerging issues that should be taken into account when building information systems on exposure include the increasing number of migrant workers carrying out work with potentially high exposures, new jobs in waste management and recycling, the use of nanotechnologies and potential risks associated with so-called ‘green jobs’. It should not be forgotten that some of the emerging risks may be caused by the use of known carcinogens in new processes and products. An example would be exposures to silica during sandblasting of textiles and when cutting artificial stone.

A socioeconomic gradient can be seen in exposures, as workers in low-qualified jobs are more often exposed and to higher levels than white-collar workers. The same is true for maintenance and sub-contracted tasks, where there are often higher exposures.

Issues relevant for people in recovery from work-related cancer when returning to work must also be identified and addressed, for example by adapting their duties, helping them to handle the stress of returning to a job that may have been related to cancer, and managing changes to work organisation and the team. This requires coordinated action of all workplace actors, and cooperation between health-care providers and workplace actors, which should also involve preventive services. Strategies need to target both women and men, and include workers in temporary and part-time jobs. Given that the working population is ageing, strategies need to be developed to maintain working capacity and ensure decent working conditions for all, including workers affected by chronic diseases. Better evidence about effective types of intervention needs to be sought. Public health stakeholders should play a bigger role than at present.

7.2. Recommendations

This report has shown that efforts are required at all levels: improved application of legislation (especially concerning process-generated factors and non-chemical factors), awareness-raising strategies to improve the risk perception of all stakeholders, specifications of comprehensive preventive measures for all work processes that involve such risk factors, improved implementation and enforcement, and lowering barriers to compensation. Regarding the last of these, Denmark has set an interesting example on lowering barriers to compensation by more or less taking over directly all factors recognised by the IARC as cancer risk factors into national regulations.

An important evaluation study of European strategy on safety and health, on behalf of the Directorate-General for Employment, Social Affairs and Inclusion, recommends a new strategy, where the focus includes occupational cancer deaths (European Commission, 2013). It should target particularly the challenges related to the implementation of the legal framework, with an explicit focus on small and medium-sized enterprises (SMEs) and micro-enterprises. For many of the key occupational carcinogens the report points out the need to change attitudes about the potential risks and clearly demonstrate to employers and workers how to reduce exposure to these agents. In this respect, stakeholders at Member State level have emphasised that the European strategy has put pressure on national policy-makers to act and thus has been an important driver for developing national strategies/action. It states that not only chemical but also biological, physical and organisational factors should be addressed by an overall policy to tackle work-related cancer. Occupational exposure rarely involves one single factor; frequently, it is a combination of factors.

The new EU Strategic Framework on Health and Safety at Work 2014-2020 (European Commission, 2014) has defined as one of its three major challenges the prevention of work-related diseases, puts emphasis on the cost of occupational cancer to workers, companies and social security systems, and highlights the importance of anticipating potential negative effects of new technologies on workers' health and safety. It also makes reference to the impact of changes in work organisation in terms of physical and mental health and calls for special attention to the related risks women face, for example specific types of cancer, as a result of the nature of some jobs where they are over-represented.

A precautionary approach is needed where uncertainties such as dealing with mixtures or having insufficient data in general are identified. There is a demand for a new cancer prevention paradigm based on an understanding that cancer is ultimately caused by multiple interacting factors. Such a precautionary approach also needs to consider changes in the world of work, such as increases in subcontracting, temporary work, multiple jobs and working at 'clients' premises with limited possibilities for adaptation, increasingly static work, the move from industry to service sectors, increasing female employment in exposed occupations, growth in atypical working times, increasing multiple exposures, and so on (EU-OSHA, 2012).

Countries such as France and Germany have chosen to apply a more systematic approach to reducing the occupational cancer burden. In France, OSH policy is integrated with other policy areas, such as the national cancer plan and the public health strategy, to make the most of the resources and their different potentials, which allows for a global scope of action. Experiences from the French example should be shared with other countries to make the best use of all available channels to enhance the prevention of work-related cancer. Another approach could be to make the reduction of exposure to carcinogens and the reduction of occupational cancer cases a goal in the national OSH strategies, as outlined by the new strategic framework for occupational safety and health.

Regarding chemicals, the positive effects of REACH and CLP could be further enhanced by better integration with OSH legislation, for example by allowing access to data generated by REACH and CLP (for example data from self-classification by registrants, meaning substances that do not have a harmonised European classification), by improving awareness, through information exchange on the challenges posed by specific exposure situations between OSH and REACH stakeholders, and so on. The communication channels along the supply chain could be better used to promote good practice in risk assessment, risk management, instruction and substitution. Where DNELs cannot be set, the concept of health-based or risk-based exposure limits has been implemented by several countries. The goal of new approaches in Germany and the Netherlands is the continuous reduction of exposure to carcinogenic chemicals towards a level of acceptance (health- or risk-based OELs). Its aim is to substantially accelerate the implementation of prevention measures. This approach should be closely monitored and evaluated.

Of the vast amount of chemicals being brought to market, only a few have been thoroughly investigated with regard to occupational cancer. This situation is improving because of REACH. However, limit values cannot be set for a number of factors because of various problems, as described in the report. Therefore, risk assessment and related preventive measures cannot rely on workplace measurements. Where the scientific data do not yet allow defining or measuring OELs (threshold- or risk-based), and risks seem possible, a precautionary approach has to be applied.

While the numbers of workers exposed to them is considerable, the problem of process-generated substances is not tackled by REACH. There are many industries, processes and occupations with cancer risks where the chemical regulations do not apply. Furthermore, work processes are changing at a fast pace and new industries and processes are being introduced, for example with the development of electronic equipment; in green jobs, such as in the green energy sector (wind energy and energy storage; in waste management; and with the increasing use of nanomaterials. There is also an increase in employment in service sectors, such as health care, where exposures are difficult to track and drugs do not fall under requirements for communication in the supply chain via safety data sheets and testing and data provision requirements.

Such approaches need to be developed by researchers and professionals, and they should be included in guidelines and tools. Ideally, these specifications should be sector/occupation-specific, covering all conditions and factors, such as chemicals, biological agents, physical factors and psychosocial agents.

There are a number of emerging risks that warrant particular attention at all levels, for example nanomaterials, endocrine disruptors and non-ionising radiation. Little is known about the effects of engineered nanoparticles on cancer or other related diseases. Conventional SDSs do not require automatic notification of nanomaterial ingredients. To increase data on nanomaterial use and exposure, France has introduced a compulsory registration scheme; similar schemes are being considered in Norway, Belgium, Denmark, Sweden and Italy. This procedure is recommended for the whole of Europe.

Projects are needed to identify worker groups at high risk of contracting occupational cancer, hidden groups and vulnerable groups; model solutions should be developed to reduce exposure for such groups or work tasks, and information on risk prevention should be disseminated to high-risk workplaces. An example of this approach is the ongoing Finnish project to identify and prevent high-exposure situations, which aims to find the work tasks that are most dangerous because of chemical risks. A precautionary approach is needed. Guidelines for companies, labour inspections and accident/health insurance organisations should preferably be interactive comprehensive risk assessment tools that cover all types of risks. Employers and workers should be informed on what to do in case of missing data or unclear results. Importantly, they should be instructed on how and when to apply the precautionary principle.

The authors of the report give an overview of possible solutions, stressing that the most effective measure is the avoidance of exposure; this principle should be strengthened by enforcing the hierarchy of control measures and putting more efforts into providing tailored guidance to enterprises. A table is included giving an overview of the measures recommended in the literature examined, as well as presenting tools, guidelines, and so on.

An overview of the findings and recommendations extensively elaborated in the conclusions chapter of the report is given in Table 3.

Table 3: Findings and recommendations

Issue	Recommendations	Remarks
Exposure assessment		
Information on occupational exposure to carcinogens in Europe is outdated and incomplete	CAREX estimates from the early 1990s should be updated	Incorporate exposure level estimates Include information by gender Assess uncertainty of the estimates
Data reflect exposures from the past, not apt for estimating present exposure and future trends	Improving the contextual data of exposure measurement databases via international cooperation would facilitate better use of exposure data in data estimations Prospective studies that incorporate trend information (exposure over time) and information on exposure patterns in different occupations and tasks	Build on examples such as the SYNERGY study, which focuses on silica exposures Build on examples from Member States, such as the prospective studies from the UK on shift work and silica exposure.
Because awareness is low and occupational history poorly monitored and described, under-recognition of female work-related cancers is likely to happen	Collect data in a gender-sensitive way, by considering equally sectors where men and women work and their typical exposures	Build on examples such as the GISCOP study, which retrospectively explores exposure histories through worker interviews combined with social security and employment data
Age-specific data on exposure is also scarce, and little is known on exposure prevalence and exposure patterns and levels for workers of different ages	Incorporate information on age and link to employment patterns in different occupations and differences in conditions for women and men	Young workers are particularly at risk in maintenance, apprenticeship, construction, service sectors and the hospitality industry
Member State sources on exposure are difficult to understand, and access for professionals from other	Promote exchange and processes that make data available	The European database Hazchem@work is expected to provide data

Issue	Recommendations	Remarks
countries is limited because of language barriers. Examples include Poland, Slovakia and the Czech Republic, as well as France and Germany.		The ongoing NECID project is developing a nanoparticle exposure database to enable uniform storage of nanoparticle exposure data and contextual information
Little information on exposure levels	Develop JEM and exposure databases to include levels of exposure and contextual data	Include the increasing number of migrant workers carrying out work with potentially high exposures, new jobs in waste management and recycling, and potential risks associated with so-called 'green jobs'
Shift work that involves circadian disruption and sedentary work were identified as potential contributing factors to development of cancer, but they have hardly received the attention they warrant.	Legislative framework and, more specifically, the directive on working time apply and preventive measures can be set following risk assessment More research on the relationship between risk and effect and on effective preventive measures Avoidance or reduction of sedentary work by using dynamic workstations and/or treadmill desks Organisation of work to avoid static work, prolonged standing and prolonged sitting, for example through breaks and reorganisation of work procedures	Build on examples of guidance, for example from Canada on schedules, avoidance of light exposure and organisation of rest periods Build on prospective studies from the UK to assess the potential impact of different measures, such as the reduction of years worked in shifts, on cancer figures
Chemical agents		
Compulsory notification of workers' exposure to chemical carcinogens is implemented to varying degrees and only for selected substances Low and occasional exposures are unreported	Set up a comprehensive national register for all countries, enabling Europe-wide data collection on carcinogen exposure Include all EU countries and all relevant carcinogenic exposures (and possibly other chemical agents of high concern) Cover temporary and subcontracted workers, and maintenance workers	Reporting may become an administrative routine Analyse results to help improve prevention Ensure reporting triggers substitution efforts

Issue	Recommendations	Remarks
The numbers of exposed are high for process-generated substances, such as hardwood dust, chromium, nitrates, PAHs and asbestos, covered by the registers	Ensure adequate information and prevention measures, although these substances are not covered by SDS and communication through the supply chain To enhance workplace protection, find ways of promoting prevention and raising awareness other than those provided by the use of SDSs and communication up and down the supply chain through the REACH processes	Apprentices and women may not be covered by exposure assessment, although exposed; avoid preconceived ideas about who is exposed and at risk More research to assess exposures to vulnerable groups
Quartz dust and diesel engine exhaust fumes and gas, welding fumes, ETS, silica, wood dust and endotoxins are not yet covered by registers, mainly because of their very wide use range	Assess exposure, broaden the scope of assessment systems to cover these substances adequately	Young workers in maintenance and women, for example in delivery, retail and transport, are insufficiently covered by data; ensure their exposures are also investigated
There is little integration between REACH and OSH legislation, and limited access to REACH information, which is important for risk assessment It is difficult to select useful information from very long safety data sheets and the databases for REACH and CLP	Access to data generated by REACH and CLP (especially from self-classification, where registrants classify substances themselves and there is no harmonised classification) should be allowed to those who protect workers Improve information exchange on exposure situations between REACH actors and OSH stakeholders SDSs and exposure scenarios should be realistic and take account of the hierarchy of control measures and the specific provisions of the Carcinogens and Mutagens Directive	Build on examples of risk assessment tools that integrate REACH information (for example Stoffenmanager and some OiRA risk assessment tools, including for service sectors such as hairdressing and retail) Build on successful electronic tools to enhance communication through the supply chain (for example SDBtransfer, an electronic process for the electronic exchange of safety-related data in the supply chain of the construction industry)
There is little knowledge about the effects of nanoparticles Conventional SDSs do not require automatic notification of nanomaterial ingredients	Consider registration and reporting schemes	Build on examples from Norway, Belgium (which will have a register from 1/1/2016), Denmark, Sweden and Italy

Issue	Recommendations	Remarks
Prevention		
Avoidance of exposure (elimination) and substitution are principles laid down in legislation, but not put into practice Companies need more guidance on avoiding and substituting carcinogenic agents/factors	Promote elimination and substitution by providing training, appropriate tools and practical examples Risk assessment tools should emphasise on substitution and elimination Hierarchy of control measures should be mainstreamed into related policy areas (REACH, machinery, PPE)	Build on examples of existing schemes, substitution databases (SubsPort, substitution-cmr.fr) and case studies of successful substitution Further develop existing databases EU guidance on substitution of chemicals is available (EU-OSHA, 2003; European Commission, 2012)
There is hardly any assessment of actions and activities to reduce exposure	Assess level of knowledge and behavioural changes in employers and workers Assess impact of campaigns and awareness-raising actions Incorporate knowledge transfer activities into campaigns, translating findings into accessible information for enterprises and practical guidance specific to risk factors and sectors, occupations and work tasks	Build on examples from Member States, such as the asbestos campaigns in the UK
Awareness is low and employers' knowledge is limited	Awareness-raising campaigns are needed, preferably as tripartite initiatives Provide detailed guidance on how to reduce exposure to specific risks Several studies show that inspected companies understood the risks much better and were more motivated to take action; a higher presence of labour inspectors and more inspections, especially in small companies, are needed Guidelines for companies, labour inspections and accident/health insurance organisations are needed Provide interactive, comprehensive risk assessment tools that cover all types of risks and allow flexible updating	Build on examples from Member States, for example the process-specific and substance-specific criteria in Germany Member States could follow the Swedish example: regional safety representatives for small workplaces are appointed by the trade unions and can inspect SMEs. The costs of the inspections are partly covered by the government; the right for 'workers' organisations to inspect jointly is also applied in other countries

Issue	Recommendations	Remarks
Awareness is very low for physical and biological agents	Expand JEMs to include risk factors other than chemicals, broadening the scope to include more substances and other factors (shift work and so on)	CAREX Canada is the most comprehensive information source, with shift work and other risk factors incorporated
Occupational exposure is rarely associated with one single factor; frequently, it is a combination of risk factors	Holistic approach Exposure profiles for specific occupations, taking into account physical, chemical, biological and work-organisational factors and considering socio-economic status. Combine exposure information with knowledge gathered from national cancer registers, disease registers and reports of cancer cases to compensation and insurance schemes. Sources such as cancer registries and exposure databases can be helpful in tracking multiple exposures and identifying possible links and synergetic or multiplicative effects between risk factors	Build on national examples of surveys (such as SUMER in France), studies on cancer in specific occupations (such as NOCCA) and occupational cancer registries that contribute to the active search for victims of work-related cancer (OCCAM, through which cases where the patient has a history of working in high-risk industries are notified to the occupational health services by Local Health Units)
In the service sector, awareness is low and workers have little training on how to protect themselves, frequently have little access to preventive services, are infrequently consulted on workplace measures and often have little autonomy.	Awareness-raising and prevention strategies are needed	Build on examples of national strategies that cover service sectors
Preventive services play an important role in exposure assessment in workplaces and giving advice to companies, but the roles and tasks of preventive services are frequently not clear, and resources are becoming scarce in some of the Member States (in particular, there is a shortage of occupational physicians)	Empower preventive services to support prevention of work-related cancer Ensure good coverage and continuous training	Build on examples from Member States that request regular retraining

Issue	Recommendations	Remarks
There is little knowledge about the impact of new forms of working (e.g. subcontracting and more fragmented working careers)	Compulsory recording of even occasional exposures Information on employment and jobs held from social security registers could be combined with exposure information to build evidence of the exposure histories of workers	Build on examples from Member States
From the point of view of prevention, it would be beneficial to estimate the future impact of present exposure	Requires information on the numbers of exposed workers and their levels of exposure over time Quantitative estimates of these are not usually available, but can be derived using job–exposure estimates	Build on examples such as the burden assessments carried out in the UK and the Finnish exposure trend analyses
Back to work		
There are hardly any return-to-work strategies, especially for workers affected by work-related cancer	Design return-to-work strategies Build on successful examples Include all actors at enterprise level and cooperate with health services Address worries of colleagues	Strategies need to target both women and men, and include workers in temporary and part-time jobs. Returning to work without being exposed to the same cancer-causing factor may be difficult

NECID, Nano Exposure and Contextual Information Database

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