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

European Risk Observatory Report

European Agency for Safety and Health at Work

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Glossary

AGS	The German Federal Committee on Hazardous Substances
ANSES	French Agency for Food, Environmental and Occupational Health and Safety
ASA Register	Finnish Register on Workers Exposed to Carcinogens
BAuA	German Federal Institute for Occupational Safety and Health
BGIA	German Institute for Occupational Safety
C&L Inventory	Classification and Labelling Inventory
CAREX	International Information System on Occupational Exposure to Carcinogens
CCOHS	Canadian Centre for Occupational Health and Safety
CCSHP	Cross-Canada Study of Pesticides and Select Cancers
CEHD	Chemical Exposure Health Data
CLP	Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures
CMR	carcinogenic, mutagenic or reprotoxicant
CoRAP	Community rolling action plan
CRAM	French regional health insurance fund
DARES	Statistical Department of the French Ministry for Labour
DFG	German Research Foundation
DG-EMPL	Directorate-General for Employment, Social Affairs and Inclusion
DGUV	German Social Accident Insurance
DNA	deoxyribonucleic acid
DNELs	derived no-effect levels
ECD	endocrine-disrupting compound
ECHA	European Chemicals Agency
ECHA-NMWG	European Chemicals Agency Nanomaterials Working Group
EEA	European Economic Area
EFTA	European Free Trade Association
EGU recommendations	recommendations from German social security organisations for risk assessment
EODS	European Occupational Diseases Statistics
EPA	US Environmental Protection Agency
ETS	environmental tobacco smoke
ETUI	European Trade Union Institute
EU-OSHA	European Agency for Safety and Health at Work
Eurofound	European Foundation for the Improvement of Living and Working Conditions

Eurostat	the statistical office of the European Union
EWCS	European Working Conditions Survey
FINJEM	Finnish Job-Exposure Matrix
FIOH	Finnish Institute of Occupational Health
GAARN	Group Assessing Already Registered Nanomaterials
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
GISCOP	French Scientific Interest Group on Occupational Cancer
HSE	United Kingdom Health and Safety Executive
IARC	International Agency for Research on Cancer
IFA	Institute of German Social Accident Insurance Institutes
ILO	International Labour Office
IMIS	Integrated Management Information System
INCA	French National Cancer Institute
INERIS	French National Competence Centre for Industrial Safety and Environmental Protection
INRS	French National Institute of Safety and Health
ISPESL	Italian National Institute of Workplace Safety and Prevention
JEM	job-exposure matrix
JSM	job-specific module
LEV	local exhaust ventilation
MAK Commission	Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area
MEGA	Measurement Data on Exposure to Hazardous Substances in the Workplace
MGU	Measurement System for Exposure Assessment of the German Social Accident Insurance
NECID	Nano Exposure and Contextual Information Database
NEDB	National Exposure Database
NHL	non-Hodgkin lymphoma
NOAA	nanoparticles, agglomerates and aggregates
NOCCA	Nordic Occupational Cancer Study
OCCAM	Occupational Cancer Monitoring
OCRC	Occupational Cancer Research Centre
ODIN	Service for the Organisation of Post-Exposure Medical Examinations
OEL	occupational exposure limit
OELV	occupational exposure limit value
OR	odds ratio
OSH	occupational safety and health
OSHA	US Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon

PCB	polychlorinated biphenyl
PEROSH	Partnership for European Research in Occupational Safety and Health
PPE	personal protective equipment
REACH	Regulation (EC) No 1907/2006 on the registration, evaluation, authorisation and restriction of chemicals
RIP-oNs	REACH Implementation Projects on Nanomaterials
SDS	safety data sheet
SIREP	Italian Information System on Occupational Exposures to Carcinogens
SIRIS	Système d'Intégration des Risques par Interaction des Scores
SubsPort	Substitiution Support Portal
SUMER survey	Medical Monitoring Survey of Professional Risks
SVHC	substances of very high concern
TNO	Netherlands Organisation for Applied Scientific Research
TRBA	technical rules on biological agents
TRGS	technical rules on hazardous substances
UNEP	United Nations Environment Programme
UVR	ultraviolet radiation
WHO	World Health Organisation
WOODEX	European information system on occupational exposure to wood dust

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.

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 5.

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

Group	Example
	Bitumen fumes Fire, combustion emissions PAHs Tobacco smoke
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)

Group	Example
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
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

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.

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 United Kingdom and the Finnish exposure trend analyses.

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 United Kingdom 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.

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

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.

Conclusions and recommendations

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.

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 little information available on exposure 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.

Young worker exposed to wood dust

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.

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	Build on examples such as the SYNERGY study, which focuses on silica exposures

Issue	Recommendations	Remarks
	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 from Member States, such as the prospective studies from the United Kingdom 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 countries is limited because of language barriers. Examples include Poland, Slovakia and the Czech Republic, as well as France and Germany.	Promote exchange and processes that make data available	The European database Hazchem@work is expected to provide data 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’

Issue	Recommendations	Remarks
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 United Kingdom 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
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

Issue	Recommendations	Remarks
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
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)

Issue	Recommendations	Remarks
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 United Kingdom
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
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

Issue	Recommendations	Remarks
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 United Kingdom 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

References

BAuA – ((Bundesanstalt für Arbeitsschutz und Arbeitsmedizin) (German Federal Agency for Occupational Safety and Health)) *Bedeutung von Mykotoxinen im Rahmen der arbeitsplatzbezogenen Gefährdungsbeurteilung (Importance of mycotoxins in workplace risk assessment. state of play report)*, Sachstandsbericht, 2007. Available at: http://www.baua.de/de/Themen-von-A-Z/Biologische-Arbeitsstoffe/ABAS/aus-demABAS/pdf/Bedeutung-von-Mykotoxinen.pdf

BAuA – ((Bundesanstalt für Arbeitsschutz und Arbeitsmedizin) (German Federal Agency for Occupational Safety and Health)) (2014). Technical Rules on Biological Agents (TRBA). Retrieved 1 April 2014, from: http://www.baua.de/en/Topics-from-A-to-Z/Biological-Agents/TRBA/TRBA.html

Bender, H.F., *Acceptable, tolerable, non-tolerable risks at the workplace,* presentation at the EU-OSHA workshop Carcinogens and Work-Related Cancer, Berlin, 2012. Retrieved 4 July 2013, from: https://osha.europa.eu/en/seminars/workshop-on-carcinogens-and-work-related-cancer/speech-venues/session-1c-cancer-prevention-action-plans-and-campaigns-to-prevent-work-related-cancer/french-governmental-plans-and-national-labour-inspectorate-campaign

Blanco-Romero, L., Vega, L., Lozano-Chavarria, L., Partanen, T., 'CAREX Nicaragua and Panama: Worker exposures to carcinogenic substances and pesticides', *Int J Occup Health* 17, 2011, pp. 251–257.

Boffetta, P., Saracci, R., Kogevinas, M., Wilbourn, J.,Vainio, H., 'Occupational carcinogens', *ILO encyclopaedia*, 2003. Available at: http://www.ilo.org/safework_bookshelf/english

Bowman, J., Touchstone, J., Yost, M., 'A population-based job exposure matrix for power-frequency magnetic fields', *J Occup Environ Hyg* 4, 2007, pp. 715–28.

CCOHS – Canadian Centre for Occupational Health and Safety (2012). 'Skin cancer and sunlight'. Retrieved 10 April 2014, from: http://www.ccohs.ca/oshanswers/diseases/skin_cancer.html#_1_2

Cherrie, J., van Tongeren, M., Semple, S., 'Exposure to occupational carcinogens in Great Britain', *Ann Occup Hyg* 51, 2007, pp. 653–664.

Clapp, R.W., Jacobs, M.M., Loechler, E.L., *Environmental and occupational causes of cancer: New evidence, 2005–2007*, Lowell Center for Sustainable Production, 2007.

Driscoll, T., Nelson, D., Steenland, K., Leigh, J., Concha-Barrientos, M., Fingerhut, M., Prüss-Üstün, A., 'The global burden of diseases due to occupational carcinogens', *Am J Indust Med* 48, 2005, pp. 419–431.

EU-OSHA – European Agency for Safety and Health at Work, *Factsheet 34: Elimination and substitution of dangerous substances*, 2003. Available at: https://osha.europa.eu/en/publications/factsheets/34

EU-OSHA – European Agency for Safety and Health at Work (2012). Workshop on carcinogens and work-related cancer. Retrieved 29 April 2014, from https://osha.europa.eu/en/seminars/workshop-on-carcinogens-and-work-related-cancer

EU-OSHA – European Agency for Safety and Health at Work (2013), *New risks and trends in the safety and health of women at work.* Available at: https://osha.europa.eu/en/publications/reports/new-risks-and-trends-in-the-safety-and-health-of-women-at-work

European Commission, *Directive 2004/37/EC of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (Sixth individual Directive within the meaning of Article 16(1) Directive 89/391/EEC)*, OJ L 158, 30.4.2004. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004L0037R%2801%29:EN:NOT

European Commission – Directorate-General for Employment, Social Affairs and Inclusion, *Minimising chemical risk to workers' health and safety through substitution*, Publications Office of the European Union, Luxembourg, 2012. Available at: http://bookshop.europa.eu/en/minimising-chemical-risk-to-workers-health-and-safety-through-substitution-pbKE3012758/?CatalogCategoryID=Ke4KABstjN4AAAEj8pAY4e5L

European Commission, Directorate-General for Employment, Social Affairs and Inclusion, *Evaluation of the European Strategy on Safety and Health at Work 2007–2012*, final report prepared by Milieu, IOM and COWI, 2013. Available at: ec.europa.eu/social/BlobServlet?docId=10016&langId=en

European Commission, *Communication from the Commission to the European Parliament, the Council, the European Economic and Cocial Committee and the Committee of the Regions on an EU Strategic Framework on Health and Safety at Work 2014-2020*, from 6 June 2014, COM(2014) 332 final. Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0332.

Heederik, D., *Endotoxins: An emerging biological risk?*, presentation at the EU-OSHA workshop Occupational Risks from Biological Agents: Facing up to the Challenges, Brussels, 6–7 June 2007. Retrieved 31 March 2014, from: https://osha.europa.eu/en/seminars/occupational-risks-from-biological-agents-facing-up-the-challenges/speech-venues/speeches/endotoxins-an-emerging-biological-risk

IARC – International Agency for Research on Cancer, *Radiation*, IARC Monographs Volume 100 D, Lyons, 2012. Available at: http://monographs.iarc.fr/ENG/Monographs/vol100D/mono100D.pdf

IARC – International Agency for Research on Cancer, *Air Pollution and Cancer*, IARC Scientific Publication No 161, 2014. Available at: http://www.iarc.fr/en/publications/books/sp161/index.php

Kauppinen, T., Karjalainen, A., Pukkala, E., Virtanen, S., Saalo, A., Vuorela, R., 'Evaluation of a national register on occupational exposure to carcinogens: effectiveness in the prevention of cancer, and cancer risks among the exposed workers', *Ann Occup Hyg* 51, 2007, pp. 463–470.

Kauppinen, T., Toikkanen, J., Pedersen, D., Young, R., Ahrens, W., Boffetta, P., Hansen, J., Kromhout, H., Maqueda Blasco, J., Mirabelli, D., de la Orden-Rivera, V., Pannett, B., Plato, N., Savela, A., Vincent, R., Kogevinas, M., 'Occupational exposure to carcinogens in the European Union', *Occ Environ Med* 57, 2000, pp. 10–18.

Kauppinen, T., Pajarskiene, B., Podniece, Z., Rjazanov, V., Smerhovsky, Z., Veidebaum, T., Leino, T., 'Occupational exposure to carcinogens in Estonia, Latvia, Lithuania and the Czech Republic in 1997', *Scand J Work Environ Health* 27, 2001, pp. 343–345.

Kauppinen, T., Vincent, R., Liukkonen, T., Grzebyk, M., Kauppinen, A., Welling, I., Arezes, P., Black, N., Bochmann, F., Campelo, F., Costa, M., Elsigan, G., Goerens, R., Kikemenis, A., Kromhout, H., Miguel, S., Mirabelli, D., McEneany, R., Pesch, B., Plato, N., Schlünssen, V., Schulze, J., Sonntag, R., Verougstraete, V., De Vicente, M.A., Wolf, J., Zimmermann, M., Husgafvel-Pursiainen, K., Savolainen, K., 'Occupational exposure to inhalable wood dust in the member states of the European Union', *Ann Occup Hyg* 50, 2006, pp. 549–561. Available at: http://www.ncbi.nlm.nih.gov/pubmed/16571638

Koeman, T., Slottje, P., Kromhout, H., Schouten, L., Goldbohm, R., van den Brandt, P., Vermeulen, R., 'Occupational exposure to extremely low-frequency magnetic fields and cardiovascular disease mortality in a prospective cohort study', *Occup Environ Med* 70, 2013, pp. 402–7.

Mirabelli, D., Kauppinen, T., 'Occupational exposure to carcinogens in Italy: an update of CAREX database', *Int J Occup Environ Health* 11, 2005, pp. 53–63.

Lavoué, J., Pintos, J., Van Tongeren, M., Kincl, L., Richardson, L., Kauppinen, T., Cardis, E., Siemiatycki, J., 'Comparison of exposure estimates in the Finnish job-exposure matrix FINJEM with a JEM derived from expert assessments performed in Montreal', *Occup Environ Med* 69, 2012, pp. 465–471.

McCausland, K., Martin, N. & Missair, A., 'Anaesthetic technique and cancer recurrence: current understanding', OA Anaesthetics, 2014 Jan 18;2(1):1. Available at: https://www.oapublishinglondon.com/article/1125

Melzer, F., 'Nur jeder fünfte Antrag kommt durch [Only every fifth application is successful]', *Metallzeitung* 2, Frankfurt, 2014.

Partanen, T., Chaves, J., Wesseling, C., Chaverri, F., Monge, P., Ruepert, C., Aragon, A., Kogevinas, M., Hogstedt, C., Kauppinen, T., 'Workplace carcinogen and pesticide exposures in Costa Rica', *Int J Occup Environ Health* 9, 2003, pp. 104–111.

Pukkala, E., Martinsen, J.I., Lynge, E., Gunnarsdottir, H.K., Sparén, P., Tryggvadottir, L., Weiderpass, E., Kjaerheim, K., 'Occupation and cancer – follow-up of 15 million people in five Nordic countries', *Acta Oncol* 48, 2009, pp. 646–790. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19925375; http://www.ncbi.nlm.nih.gov/pubmed/19925375 and http://astra.cancer.fi/NOCCA/full-article.html

Rushton, L., Hutchings, S., Brown, T., 'The burden of cancer at work: estimation as the first step to prevention', *Occup Environ Med* 65, 2008, pp. 789–800.

Siemiatycki, J., Richardson, L., Straif, K., Latreille, B., Lakhani, R., Campbell, S., Rousseau, M-C. & Boffetta, P., 'Listing occupational carcinogens', *Environmental Health Perspectives*, 112(15), 2004. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1247606/pdf/ehp0112-001447.pdf

Wriedt, H., *The German exposure risk management model,* presentation at the EU-OSHA workshop Carcinogens and Work-Related Cancer, Berlin, 2012. Retrieved 4 July 2013, from: https://osha.europa.eu/en/seminars/workshop-on-carcinogens-and-work-related-cancer/speech-venues/session-1c-cancer-prevention-action-plans-and-campaigns-to-prevent-work-related-cancer/french-governmental-plans-and-national-labour-inspectorate-campaign

1. Introduction

Occupational cancer is a problem that needs to be tackled across the 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 (see, for example, Rushton *et al.*, 2012). Accordingly, the European Agency for Safety and Health at Work (EU-OSHA) regards work-related cancer as a major issue for occupational safety and health (OSH), and, among other activities, it organised a workshop in Berlin in 2012 where experts from all relevant fields of expertise discussed monitoring, vulnerable groups and prevention strategies. EU-OSHA commissioned this report as a follow-up to this workshop.

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;
- make some recommendations for filling in gaps in relevant knowledge needed to prevent effectively future risks of occupational cancer

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

Some vulnerable groups of workers (for example women, young workers, workers experiencing high exposure to carcinogens, workers in precarious conditions) are described when discussing occupational exposure to carcinogenic factors and preventive approaches.

Less attention will be paid to topics which 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)).

Target groups
This report is aimed at OSH researchers and policy-makers, including social partners. It may also be useful to OSH prevention experts, for priority setting, and to those who deal with workplace risk assessment.

2. Risk factors for work-related cancer and occupational exposure to carcinogens

2.1. Risk factors

In the 18th century, Percivall Pott was the first to describe occupational cancer, caused by soot, in chimney sweeps (Brown & Thornton, 1957). He carefully analysed the working conditions of his patients, following the example of Bernardino Ramazzini, the so called 'father of occupational medicine', who laid its foundations in the 17th century (Franco, G. & Franco, F., 2001). Up to the 1970s, most recognised human carcinogenic factors were found primarily in the occupational environment. Human carcinogens first identified in this setting include chemicals such as arsenic, asbestos, benzene, chromium, nickel, radon and vinyl chloride (Siemiatycki *et al.*, 2004). In 1926, Hermann Joseph Muller discovered a clear connection between X-rays and lethal mutations, widening the scope to physical factors (Muller, 1926).

Monograph evaluations by the IARC (International Agency for Research on Cancer) show that occupational factors still represent a high percentage of factors classified as 'probable' and 'possible' human carcinogens (Blair, Marrett & Freeman, 2011).

Direct evidence concerning carcinogenicity is provided by epidemiological studies on humans or experimental studies of animals (usually rodents). Additional evidence may be provided by the results of studies of absorption and metabolism, physiology, mutagenicity, cytotoxicology, and by chemical structure–activity analysis.

Meanwhile, the list of chemicals has greatly expanded, and other cancer risks have been identified, such as ergonomic, organisational, and biological factors. These factors are presented in more detail in the following sections and an overview is given in Table 5 and Table 6 below.

2.1.1. Chemical risk factors

Chemical risk factors are substances or mixtures thereof which cause or promote cancer in exposed workers. Such substances can be classified as carcinogenic by scientists, scientific panels and/or regulators. The most authoritative body in this respect is the Lyon-based International Agency for Research on Cancer (IARC), an agency of the World Health Organisation (WHO).

IARC sets up scientific panels to discuss and assess the available evidence regarding the substances, factors or mixtures in question. They are classified into one of the following groups: carcinogenic (group 1), probably carcinogenic (group 2A), possibly carcinogenic (group 2B), not classifiable (group 3) and probably not carcinogenic (group 4). So far, IARC has identified more than 100 substances or substance groups as carcinogenic and some 300 as probably or possibly carcinogenic (IARC, 2013).

The IARC classification is not, however, legally binding. The legally binding European Union definition and classification of chemical carcinogens is included in the EU CLP regulation on the classification, labelling and packaging of substances and mixtures (Regulation (EC) No 1272/2008), in line with the UN's Globally Harmonized System of Classification and Labelling of Chemicals (GHS) scheme. It defines category 1, substances known (1A) or presumed (1B) to be human carcinogens; and category 2, suspected human carcinogens (EC, 2008a). Directive 2004/37/EC (on the protection of workers from the risks related to exposure to carcinogens or mutagens at work) defines "carcinogen" as "a substance or mixture which meets the criteria for classification as a category 1A or 1B carcinogen set out in Annex I to the CLP Regulation" (European Commission, 2004).

For a long time, testing and assessing chemicals was seen primarily as a government responsibility. This proved difficult because of the large number of new chemicals launched on the market. REACH, the EU regulation on the registration, evaluation, authorisation and restriction of chemicals (Regulation (EC) No 1907/2006), has shifted the responsibility to companies that develop or market chemicals. This is expected to improve the general situation on data availability.

REACH required notification by 3 January 2011 of all substances placed on the EU market as of 1 December 2010, and notification of new substances within one month of their placement on the market. In most cases, suppliers need to decide on the classification of a substance or mixture. This is called self-classification.

There are normally four basic steps to self-classify a substance or a mixture:

1. collection of available information;
2. evaluation of the adequacy and reliability of the information;
3. review of the information against the classification criteria;
4. decision on classification.

All previously harmonised substance classifications under the former legislation (the Dangerous Substances Directive) have been converted into CLP harmonised classifications.

Table 4: Number of carcinogens under the harmonised classification and labelling

Category of carcinogen	Number of substances
1A	189
1B	826
2	188
Total	1,203

Source: European Commission, 2008a; Musu, 2014,

Manufacturers, importers and downstream users need to follow new scientific or technical developments and estimate whether a re-evaluation of the classification of the substance or mixture they place on the market should be made. In some cases, however, the decision on the classification of a chemical is taken at Community level (such decisions are published on the website of the European Chemicals Agency (ECHA)), for example for CMR substances (carcinogens, mutagens and reprotoxicants) or for sensitisers.

The CLP (Art. 42) requires that ECHA shall maintain a Classification and Labelling (C&L) Inventory holding all the notification information. Certain elements of the database should be made publicly accessible (the public C&L Inventory). ECHA has currently received well over 5 million notifications for more than 140,000 individual substances, and the database grows every day; of the notified substances, approximately 2,800 are self-classified as carcinogenic category 1A, 1B or 2. The C&L Inventory database (including substances in Annex VI to the CLP, with harmonised classification) is available at the ECHA website (ECHA, 2014b).

ECHA provides information and support in the form of Questions & Answers, Technical FAQs and guidance sheets for using the database and for the notification process. There may be duplications and conflicts among the database notifications, which have to be revised and evaluated.

While REACH is expected to improve data availability, it must nevertheless be noted that it has limitations: it does not require epidemiological evidence, and testing requirements are regulated according to the tonnage, that is the annual tonnage produced/imported of each chemical by producer/registrant. More information is given in Chapter 4.

Information on the classified substances is available from different websites:

- The IARC lists can be viewed or downloaded at the IARC website (IARC, 2014a).
- The CLP list: 'Harmonised classification and labelling for certain hazardous substances' is presented in Annex VI to the directive (European Commission, 2008a).
- Other classifications are available from the ECHA C&L database.
- The Candidate List of Substances of Very High Concern for Authorisation (published in accordance with Article 59(10) of REACH and continuously updated) can be viewed at the ECHA website.

Other important laws at European level are Directive 2004/37/EC on carcinogens or mutagens at work (the Carcinogens Directive) and Directive 98/24/EC on risks related to chemical agents at work (the Chemical Agents Directive). These directives define the framework for worker protection and are described further in Chapter 4.

The pattern and variety of recognised occupational diseases linked to exposure to chemicals varies greatly across Member States. Only a very limited number of chemicals or mixtures are recognised as causative factors in the lists of individual Member states making it difficult for workers to claim compensation. The European legislative framework for the recognition of occupational cancers is described in Chapter 4, Section 4.2.2.

2.1.2. Environmental tobacco smoke

In the last years, as many as 17 Member states have introduced legislation to ban environmental tobacco smoke from public places, incl. workplaces. A short overview of legislation related to tobacco smoke and EU-OSHA activities to support the European Commission´s activities is given in section 4.

A Eurobarometer survey of March 2009 (European Commission, 2009b) found 84% of EU citizens in favour of smoke-free offices and other indoor workplaces, 79% in favour of smoke-free restaurants, and 61% supporting smoke-free bars and pubs. A fifth of respondents working outside the home had to do so in places where they were exposed to tobacco smoke on a daily basis – over half of them for at least one hour a day. There were considerable difference between Member states.

Currently, the main occupations where workers are exposed to ETS are those taking place in environments where smoking is still permitted. The exposed workers include outdoor occupations such as farming, fishing, construction and landscaping; "in-house" workers including caregivers and tradespeople who enter private residences to provide a service; hospitality workers (i.e. in the service industry in some countries, in casinos and gaming rooms), emergency workers and law enforcement officers, for example in prisons (CAREX Canada).

Several studies from Spain, Italy and Portugal found that smoking bans had reduced consumption and led to reductions in exposure measured by fine particle exposure (Pacheco *et al.*, 2012; Gorini, 2011), vapour-phase nicotine concentrations and biological monitoring of hospitality workers (Fernández *et al.*, 2009; Nebot *et al.*,2009).

However, the studies also found that exposure levels were still high for workers in areas where smoking was allowed, for example in separate smoking areas in restaurants and bars, and that partial restrictions on smoking in hospitality venues do not sufficiently protect hospitality workers against ETS or its consequences for health, incl. respiratory health (Fernández *et al.*, 2009; Pacheco *et al.*, 2012; Polańska, 2011).

2.1.3. New and emerging chemical risks

As well as known and established risk factors including chemicals, radiation and biological factors, scientists have identified other factors and conditions that could cause cancer, such as emerging risks from nanomaterials, for example carbon nanotubes, and from endocrine-disrupting compounds (EDCs) (CDC, 2013; Clapp, Jacobs & Loechler, 2007). Some of these are not yet included in the IARC lists.

Clapp and colleagues detailed new evidence on environmental and occupational causes of cancer in a 2007 study (Clapp, Jacobs & Loechler, 2007). Despite weaknesses in some individual studies, they concluded that publications have strengthened the evidence linking specific exposure types with increased risk of cancers, including:

- breast cancer from exposure to pesticides prior to puberty;
- leukaemia from exposure to 1,3-butadiene;
- lung cancer from exposure to air pollution;
- non-Hodgkin lymphoma (NHL) from exposure to pesticides and solvents;
- prostate cancer from exposure to pesticides, polycyclic aromatic hydrocarbons (PAHs), and metal-working fluids or mineral oils.

Clapp *et al.* cite findings from the Agricultural Health Study (Alavania *et al.*, 2005) which suggest that several other cancers may be linked to a variety of pesticides.

Endocrine-disrupting compounds

In February 2013, the World Health Organisation (WHO) and the United Nations Environment Programme (UNEP) published a report on EDCs.

The authors highlighted emerging evidence of a link between exposure to EDCs and an increase in certain cancers such as breast, endometrial, ovarian, testicular, prostate and thyroid cancers, stating that these have been increasing over the past 40–50 years (WHO & UNEP, 2012). The authors mention occupational exposure to pesticides, to some polychlorinated biphenyls (PCBs) and to arsenic as causes of prostate cancer. The European Commission organised a conference on 'Endocrine disruptors: Current challenges in science and policy' on 11 and 12 June 2012. The presentations and discussions covered the effects of endocrine disruptors on human health and the environment, the risks, the identification of endocrine disruptors and policy objectives. The European Commission is currently working on a redefinition of the term 'endocrine-disrupting substance'.

Recently, EU-OSHA organised a seminar on workplace risks to reproduction, as many of these substances are also reprotoxicants. More detail on these substances is included in an EU-OSHA report (EU-OSHA, in press), and in the workshop proceedings (EU-OSHA, 2014).

Nanomaterials

With regard to nanomaterials, an EU-OSHA literature review (EU-OSHA, 2009b) stated that long-term animal studies with intratracheal instillation performed with nanostructured carbon black, aluminium oxide, aluminium silicate, titanium dioxide (hydrophilic and hydrophobic) and amorphous silicon dioxide resulted in tumours induced by all tested nanomaterials. Microsized fine particles also caused tumours in these studies, but the potency of the nanomaterials (volume basis) was calculated at 5 to 10 times higher. Some types of carbon nanotubes may lead to asbestos-like effects.

In particular, the increased surface area (in relation to the decreased particle diameter) is thought to be the cause of the increased toxicity of some granular nanomaterials in the lungs. Some authors argue that lung tumours can only occur in cases of lung overload and subsequent reactions such as inflammation and fibrosis. According to this theory, tumour development clearly depends on non-neoplastic prelesions (for example, inflammation, fibrosis). Other authors consider this theory insufficiently supported. The direct interaction of particles (or compounds generated by particles) with DNA is considered possible, which implies a higher risk of carcinogenicity. This dispute is currently undecided and therefore the precautionary principle should be applied (EU-OSHA, 2009b).

The IARC reviewed the carcinogenicity of fluoro-edenite, silicon carbide (SiC) fibers and whiskers, and carbon nanotubes (CNT) in autumn 2014 (Grosse *et al.*, 2014). Fluoro-edenite fibrous amphibole was classified as carcinogenic to humans (Group 1) on the basis of sufficient evidence in humans that exposure to fluoro-edenite causes mesothelioma. According to the summary, SiC particles are manufactured mainly by the Acheson process, with SiC fibers being unwanted byproducts. Occupational exposures associated with the Acheson process were classified as carcinogenic to humans (Group 1) on the basis of sufficient evidence in humans that they cause lung cancer. Since the correlation between exposures to SiC fibres and cristobalite made it difficult to disentangle their independent effects, the Working Group concluded that fibrous SiC is possibly carcinogenic to humans (Group 2B) based on limited evidence in humans that it causes lung cancer. Although not unanimous, the Working Group classified SiC whiskers as probably carcinogenic to humans (Group 2A) rather than possibly carcinogenic to humans (Group 2B), on the basis that the physical properties of the whiskers resemble those of asbestos and erionite fibres, which are known carcinogens. In addition, the results of available mechanistic studies were consistent with proposed mechanisms of fibre carcinogenicity. MWCNT-7 was classified as possibly carcinogenic to humans (Group 2B); and SWCNTs and MWCNTs excluding MWCNT-7 were categorised as not classifiable as to their carcinogenicity to humans (Group 3). These assessments will be published as Volume 111 of the IARC Monographs (IARC, 2014a).

According to the European Commission Communication 'Regulatory aspects of nanomaterials' (European Commission, 2008b), all nanomaterials in chemical substances must meet the requirements of REACH. However, there are no provisions in REACH referring explicitly to nanomaterials and the implementation needs to be further elaborated. The Commission initiated REACH Implementation Projects on Nanomaterials (RIP-oNs) in 2009 in order to evaluate the applicability of the existing guidance to nanomaterials. The project relevant to information requirements under REACH (RIP-oN2) proposed guidance updates regarding information requirements on aspects such as relevance to nanomaterials and the adequacy of test methods (Hankin *et al.*, 2011). The objectives of the RIP-oN 3 project were to develop advice on how to do exposure assessment for nanomaterials within the REACH context to cover the development of Exposure Scenarios, the evaluation of operational conditions and risk management/mitigation measures and exposure estimation, and to develop ideas for how to conduct hazard and risk characterisation for nanomaterials (Aitken *et al.*, 2011). In October 2012, ECHA established a nanomaterials working group (ECHA-NMWG) to discuss scientific and technical questions relevant to REACH and CLP processes. It is an informal advisory group consisting of experts from Member States, the European Commission, ECHA and accredited stakeholder organisations, with the mandate to 'provide informal advice on any scientific and technical issues regarding the implementation of REACH and CLP legislation in relation to nanomaterials', and to have discussions with industry regarding the intrinsic properties of nanoforms and its obligation to help fulfil REACH requirements. There is a group assessing already registered nanomaterials (GAARN), which was established in January 2012 by DG Environment from the European Commission and is chaired by ECHA. The purpose of GAARN is to build a consensus in an informal setting on best practices for assessing and managing the safety of nanomaterials under REACH. Documents on progress and guidance from the group are available from the ECHA website nanomaterials pages.

The European Commission has announced the launch of an impact assessment to identify and develop the most adequate means to increase transparency and ensure regulatory oversight on nanomaterials. Results of the consultation are available (European Commission, 2014)

Several Member States have initiated registration of nanomaterials (France, Denmark, Belgium and Norway) and the Commission has consulted on a European register of nanomaterials (European Commission, 2014). The obligation to register nanomaterials with the Danish EPA's Nano Product Register only applies to nanomaterials in mixtures and articles that are intended for sale to the general public (more information can be found on the Nano Product Register's webpage: http://eng.mst.dk/topics/chemicals/nanomaterials/). Nanomaterials for occupational use are not covered by the register. For Belgium, the Royal Decree establishing the Belgian nanoregister has been published in September 2014. Substances will have to be registered from 1/1/2016 on, mixtures from 1/1/2017 on.

For future research on exposure to manufactured nanoparticles, agglomerates and aggregates (NOAA), an occupational exposure database is needed. A Partnership for European Research in Occupational Safety and Health (PEROSH) group, led by the Institute of German Social Accident Insurance Institutes (IFA) and the Netherlands Organisation for Applied Scientific Research (TNO), is currently developing such a database on an international level to facilitate the future sharing of exposure data on NOAA. The aim of the database is to help the user to fulfil the requirements on information gathering for occupational exposure assessment and to provide a general overview of results of exposure measurements against nanomaterial in different exposure situations. The exposure data of different research institutes in different countries will be collected and stored in a common database.

The intended target group is research institutes, but access to the database might be extended to third parties. The project addresses different user-specific rights and legal agreements for the handling and storage of data and the required IT security, as these matters play a critical role for a multinational database and the possibility of data sharing. The Nano Exposure and Contextual Information Database (NECID) should provide a sustainable source of information for risk management and the development of occupational exposure benchmark levels/limits (PEROSH, 2014).

2.1.4. Biological risk factors

Biological agents can cause cancer, either by direct effect (as in the case of hepatitis) or via the toxic substances that they produce (as in the case of aflatoxins, which are among the most potent poisons). Ochratoxin A, a toxin produced by *Aspergillus ochraceus*, *Aspergillus carbonarius* and *Penicillium verrucosum*, is one of the most abundant food-contaminating mycotoxins. Exposure of workers is possible during bulk handling of agricultural foodstuffs (nuts, grain, maize, and coffee), animal feed production, brewing/malting, waste management, composting, food production and horticulture. IARC lists 10 viruses and bacteria, plus a number of mycotoxins, as carcinogens (BAuA, 2007; Heederik, 2007; IARC, 2012a).

European Directive 2000/54/EC on biological agents at work regulates the exposure of workers to hazardous biological substances, although cancer is not specifically mentioned. However, it differentiates between intentional and unintentional exposure. Awareness of unintentional exposures is generally low and there is only very patchy information available on the microorganisms involved. Some of it is summarised in Table 5.

2.1.5. Radiation

Ionising radiation can cause lethal mutations. This was known apply to X-rays but has been widened to any sort of ionising radiation, such as rays caused by radioactive decay, cosmic radiation and so on.

Ultraviolet radiation (UVR) from sunlight or artificial sources (such as welding) can cause skin cancers. Exposure to electrical arc welding is associated with increased risk of ocular melanoma (HSE, 2012). Consequently, IARC has listed these types of radiation in the relevant publications (IARC, 2012b). Other sources of artificial optical radiation include the use of sun beds and sunlamps and the exposure to fluorescent lamps at work.

Among the non-melanoma skin cancers, basal cell carcinoma appear to be more closely related to intermittent solar exposure and sunburn, while the risk for squamous cell carcinoma is a result of lifetime cumulated exposure to UVR. Cancer incidence also strongly depends on the cultural norms of the country and the socioeconomic group (fair-skinned populations may be more prone to protect skin), the potential to be exposed at work due to climate and residential location, and the sector in which people work. This may partly explain the socioeconomic differences in cancer incidence that are observed in different groups and a certain “protective effect” of occupational exposure observed in some studies (HSE, 2012).

In terms of worker protection legislation, ionising radiation is covered by Directive 2013/59/Euratom (European Council, 2014), which sets limits for the amount of this type of radiation to which workers can be exposed. Optical radiation from artificial sources is covered by Directive 2006/25/EC on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation) (European Parliament and European Council, 2006). Sunlight is not covered by specific EU workplace legislation, but the provisions of Directive 89/391/EEC (the OSH Framework Directive) and all related directives apply.

2.1.6. Emerging physical risks

- **Non-ionising radiation**

The carcinogenicity of non-ionising radiation has long been a subject of scientific research. Clapp and colleagues described new evidence in a 2007 study on environmental and occupational causes of cancer (Clapp, Jacobs & Loechler, 2007). Despite weaknesses in some individual studies, they concluded that recent publications had strengthened the evidence linking specific exposure types with increased risk of cancer, among them exposure to nonionizing radiation, particularly radiofrequency fields emitted by mobile telephones, and brain cancer.

Radiofrequency electromagnetic fields are listed by IARC in group 2B. Directive 2013/35/EU on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) applies in the European Union. There is, however, no specific mention of cancer risks.

Heat shock

There is some evidence that heat shock leads to deoxyribonucleic acid (DNA) damage causing cells to switch to high mutation rates for several cell generations (Fabre and Roman, cited in Cairns, 2011). Heat shock may occur in occupations such as furnace and smelter operators, or industries such as casting factories and so on.

2.1.7. Shift work that involves circadian disruption

Shift work that involves circadian disruption was evaluated for the first time in 2007 and is now listed as a probable human carcinogen by IARC (IARC, 2010). Shift workers suffer from a disruption of the sleep–wake rhythm, insomnia and a lack of melatonin. Exposure to light at night, including a disturbance of the circadian rhythm, possibly mediated via the melatonin synthesis and clock genes, has been suggested as a contributing cause of breast cancer. Since shift and night work are prevalent and increasing in modern societies, people who engage in night shift work may exhibit altered night-time melatonin levels and reproductive hormone profiles that could increase the risk of hormone-related diseases, including breast cancer. Any measure that helps regulate the melatonin levels may help to reduce these effects (for example specific shift schedules, avoiding daylight exposure after shifts, organisational measures to regulate sleep after shifts, melatonin ingestion). According to the IARC monographs, eight studies reported relative risk estimates for histologically confirmed breast cancer for female night shift workers, with vastly differing definitions of shift work in each study. Cases of breast cancer linked to prolonged shift work have been recognised as occupational disease and compensated in some countries. Preventive measures such as limiting years of exposure to night shift work or adapting shift schedules have been proposed as strategies to limit these effects.

The specific issue of shift work/night work and cancer has not yet been specifically addressed in European legislation. However, the legislative framework and, more specifically, the directives on working time apply (Directive 2003/88/EC on working time, Directive 2002/15/EC on working time of persons performing mobile road transport activities and Directive 2000/79/EC on working time in civil aviation), and preventive measures can be taken following risk assessment.

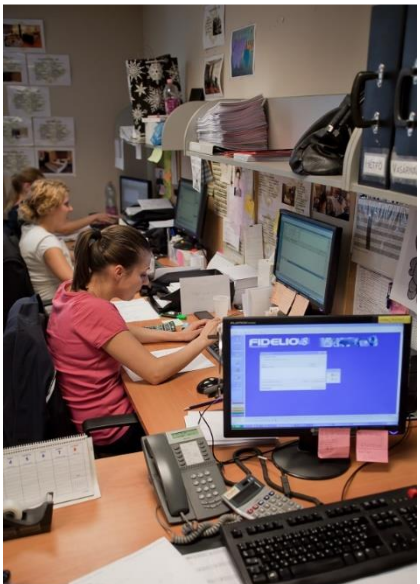
2.1.8. Other work organisational factors

Work organisational factors may also cause cancer, according to the Nordic Occupational Cancer Study (NOCCA), a large cohort study based on follow-up of the entire working populations in censuses in Denmark, Finland, Iceland, Norway and Sweden.

Stress

In a 2003 literature review, Fox concludes that stress – regardless of type, severity or exposure duration – has little or no effect on subsequent cancer incidence (Fox, 2003). He states that it is reasonable to suggest that the same results apply in the work situation. As for cancer prognosis, too few studies have been done to draw any conclusions, even tentative ones, about stressors. It is, however, possible that strong social support may slightly decrease incidence, and perhaps increase survival. However, it has to be noted that strategies for coping with stress may involve increased smoking, drinking, eating and/or use of drugs, thereby increasing the risk of cancer.

2.1.9. Sedentary work



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Boyle and colleagues conducted a population-based case–control study of colorectal cancer in Western Australia in 2005–7 (Boyle *et al.*, 2011) and found that long-term sedentary work may increase the risk of distal colon cancer and rectal cancer (tumours that develop in the large intestine). A German study using data from a cancer registry (Yousif *et al.*, 2013) revealed an increased risk of testicular cancer for technicians and related professionals and clerical support workers. The authors noted that this could be related to socioeconomic status or sedentary lifestyle, two factors that had been identified in previous studies. However, incomplete occupational data and the difficulty of finding an adequate control group to compare data with represent challenges to the validity of this approach.

2.1.10. Socioeconomic status

Socioeconomic status (and thus, presumably, lifestyle) has been described as a risk factor for skin melanoma (Martinsen *et al.*, 2008). Martinsen *et al.* studied variations in incidence of skin melanoma in the five Nordic countries by occupation and socioeconomic status. They compared information on occupation of 15 million workers based on five censuses with national death and cancer registries. The highest risk was found in dentists, while managers also had an increased risk. The lowest risk was found in fishermen, and all unskilled workers also had a decreased risk. Surdu et al found a protective effect of occupational exposure to natural UV radiation that was unexpected, and limited to light-skinned people, suggesting adequate sun-protection use (Surdu *et al.*, 2014). As mentioned in section 2.1.5. the relationship between occupational factors and skin cancer is not so clearcut, as it depends on the combination of lifestyle factors, behaviours and norms, as well as geographical latitude and individual parameters such as skin type.

Socioeconomic factors were also identified as an issue in the NOCCA study linking specific occupations to work-related cancers. One of the contributing factors is certainly the fact that low-skilled workers tend to be exposed to more physically straining work and work involving exposures to chemical and physical risks, for example in manufacturing. This issue was also discussed in EU-OSHA's workshop on cancer and carcinogens (EU-OSHA, 2012). Lynge (2012) concluded that obesity, tobacco smoking, alcohol use, drug use and other similar factors are not solely linked to personal lifestyle habits but also determined by living conditions (such as economic insecurity) which may relate to occupation. Finally, possibilities for adopting a healthier lifestyle may be limited in professions where workers have limited access to healthy food or other facilities. This might apply, for example, to professional drivers or courier workers, night workers or workers on mission or working at clients' premises.

2.1.11. Summary: overview of cancer risk factors

The following tables provide an overview of occupational carcinogenic factors and the main sectors/occupations affected.

On establishing a list of occupational carcinogenic factors (see overview and examples below), Siemiatycki and colleagues developed and applied the following rule: a factor was considered an occupational exposure if significant numbers of workers had been exposed at significant levels (Siemiatycki *et al.*, 2004).

In order to prohibit, restrict or allow use/exposure under certain conditions (see Chapter 4), the classification and background knowledge of use and risks have to be translated into legislation.

Table 5: 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, e.g. ceramic fibres
Solids	Lead Nickel compounds Chromium VI compounds Arsenic Beryllium Cadmium Carbon black Bitumen
Fumes, smoke	Welding fumes Diesel emissions Coal tar fumes

Group	**Example**
	Bitumen fumes Fire, combustion emissions PAHs Tobacco smoke
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, 2014b)
EDCs	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)

Group	Example
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
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 and b

Boffetta and colleagues note that the current understanding of the relationship between occupational exposure and cancer is far from complete (Boffetta *et al.*, 2003). 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. Often, no specific agents can be identified as aetiological factors, making it additionally complicated to translate the knowledge into worker protection legislation or classification of chemicals, because legislation as it stands often requires clearly defined factors and proof of causal relationships. See Table 6.

Table 6: Occupations or industries that have been evaluated by IARC as definitely (group 1), probably (group 2A) or possibly (group 2B) entailing excess risk of cancer among workers

Occupation or industry	Suspected substance	Sites
Aluminium production	Pitch volatiles; aromatic amines	Lungs, bladder
Arsenical insecticide production and packaging	Arsenic compounds	Lungs
Auramine manufacture	2-naphthylamine; auramine; other chemicals; pigments	Bladder
Battery manufacture	Cadmium and cadmium compounds	Respiratory and digestive systems, prostate
Beer brewers	Alcohol	Upper aero-digestive tract
Beryllium refining and machining; production of beryllium-containing products	Beryllium and beryllium compounds	Lungs
Boot and shoe manufacture and repair	Leather dust; benzene and other solvents	Lymphatic and haemopoietic system (leukaemia), nose, paranasal sinuses, bladder
Butchers and meat workers	Viruses; PAHs	Lungs
Carpentry and joinery	Wood dust	Nose and sinonasal cavities
Ceramic and pottery workers	Crystalline silica	Lungs
Coal gasification	Coal tar; coal tar fumes; PAHs	Skin (including scrotum), bladder, lungs
Coke production	Coal tar fumes	Skin (including scrotum), lungs, bladder, kidneys
Dry cleaning	Solvents and chemicals used in ‘spotting’	Lymphatic and haemopoietic system (leukaemia), brain (tumours), liver, bile ducts
Electricity: generation, production, distribution, repair	Extremely low-frequency magnetic fields; PCBs	Lungs, sinonasal cavities
Electroplating	Chromium VI compounds; cadmium and cadmium compounds	Lungs, sinonasal cavities
Epichlorohydrin production	Epichlorohydrin	Lungs, lymphatic and haemopoietic system
Ethylene oxide production	Ethylene oxide	Lymphatic and haemopoietic system (leukaemia), stomach

Occupation or industry	Suspected substance	Sites
Farmers, farm workers	Not identified	Lymphatic and haematopoietic system (leukaemia, lymphoma)
Fishermen	UVR	Skin, lips
Flame retardant and plasticiser use	PCBs	Nasopharynx, sinonasal cavities
Furniture and cabinet making	Wood dust	Nose and sinonasal cavities
Gas workers	Coal carbonisation products; 2-naphthylamine	Lungs, bladder, scrotum
Glass workers (art glass, glass containers and pressed glassware)	Arsenic and other metal oxides; antimony oxides asbestos; lead; silica; PAHs	Lungs
Hairdressers and barbers	Dyes (aromatic amines, amino-phenols with hydrogen peroxide); solvents; propellants; aerosols	Bladder, lungs, lymphatic system (non-Hodgkin lymphoma), ovaries
Hematite mining (underground with radon exposure)	Radon daughters; silica	Lungs
Iron and steel founding	PAHs; silica; metal fumes; formaldehyde	Lungs
Isopropanol manufacture (strong-acid process)	Diisopropyl sulfate; isopropyl oils; sulphuric acid	Paranasal sinuses, larynx, lungs
Magenta manufacture	Magenta; ortho-toluidine; 4,4´-methylenebis (2-methylaniline); ortho-nitrotoluene	Bladder
Mechanics, welders, etc. in motor vehicle manufacturing	PAHs; welding fumes; engine exhaust	Lungs
Medical personnel	Ionising radiation	Skin, lymphatic and haemopoietic system (leukaemia)
Painters	Not identified	Lungs, bladder, stomach
Petroleum refining	PAHs	Bladder, brain, lymphatic and haemopoietic system (leukaemia)
Pickling operations	Inorganic acid mists containing sulphuric acid	Sinonasal cavities, lungs

Occupation or industry	**Suspected substance**	**Sites**
Printing processes	Solvents; inks; oil mist	Lymphocytic and haemopoietic system, mouth, lungs, kidney
Roofers, asphalt workers	PAHs	Lymphopoietic tissue, lungs
Pulp and paper mill workers	Not identified	Lungs, bladder, lymphatic and haemopoietic system (leukaemia)
Railway workers, filling station attendants, bus and truck drivers, operators of excavating machines	Diesel engine exhaust; extremely low-frequency magnetic fields	Bladder, stomach, larynx, lymphatic and haemopoietic system (leukaemia), lungs
Rubber industry	Aromatic amines; solvents	Bladder, stomach, larynx, lymphatic and haemopoietic system (leukaemia), lungs
Synthetic latex production, tyre curing, calendering operatives (calendering is a finishing process used on cloth), reclaim rubber, cable makers	Aromatic amines	Bladder
Textile manufacturing industry	Textile dust in the manufacturing process; dyes and solvents in dyeing and printing operations	Bladder, sinonasal cavities, mouth
Sandblasting of textiles (e.g. jeans)	Silica dust	Lungs
Vineyard workers using arsenic insecticides	Arsenic compounds	Lungs, skin, lips

Source: compiled by the authors, adapted from Siemiatycki *et al.*, 2004, and Boffetta *et al.* 2003

Boffetta and colleagues also note that establishing and interpreting these lists is complicated by a number of factors (Boffetta *et al.*, 2003):

- Information on industrial processes and exposures is frequently poor, not allowing a complete evaluation of the importance of specific carcinogenic exposures in different occupations or industries.
- Exposures to well-known carcinogens, such as vinyl chloride and benzene, occur at different intensities in different occupational situations.
- Over time, changes in exposure levels occur in the workplace, as carcinogenic agents may be substituted or, more frequently, as new industrial processes or materials are introduced.
- Occupational exposure lists can refer to only the relatively small number of chemicals that have been investigated with respect to the presence of a carcinogenic risk.

This illustrates the limitations of a classification of this type, and in particular its generalisation to all workplaces. The presence of a carcinogen in an occupational situation does not necessarily mean that workers are exposed, while the absence of identified carcinogens does not exclude the presence of yet unidentified causes of cancer.

While only a small number of chemical exposures have been investigated with regard to occupational cancer, it must be stressed that it is not caused only by radiation and chemicals; it can be the result of other factors, as described above. Furthermore, occupational exposure is rarely about one single factor; rather, it generally involves a combination of factors, such as when shift-working cleaners in a hospital use hydrocarbons while cleaning near machines that emit electromagnetic radiation. This needs greater attention. Looking at cancer rates by occupation or mapping exposures in different jobs could help to identify risky professions and work procedures.

2.2. Data sources for occupational exposure to carcinogens

Some countries have established national registers covering exposure to selected carcinogens, which provide data on the numbers of exposed workers and the types of exposure (see Section 2.2.1). Concentrations of many carcinogens have also been measured in workroom air. Data on the results of industrial hygiene measurements have been computerised in many countries (see Section 2.2.2). There are also international and national information systems about carcinogen exposure which are based not on notifications of exposed workers or workplaces but instead rely on estimations of numbers of exposed workers and their level of exposure to selected carcinogens (see Section 2.2.3). In addition, there are some other exposure information systems which cover chemical agents, and which include also some estimates and information about carcinogens (see Section 2.2.4). Some of these sources contain information also on non-chemical carcinogens or suspected carcinogens (such as ionising or UVR, electromagnetic fields and night shift work); these sources are tabulated in Section 2.2.5 along with some new sources, such as international surveys. Information about 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 is described in Section 0

2.2.1. National registers on occupational exposure to carcinogens

National registers on exposure to carcinogens were set up following policy and legislative initiatives by the International Labour Organisation (ILO) (for example ILO recommendation R 147) and the EU (the Carcinogens Directive).

The use of selected systems is described below, including how they can contribute to reducing exposures, raising awareness and preventing cancers.

- **ASA Register (Finland)**

The recommendation of the ILO that a monitoring system on workers exposed to carcinogens should be established prompted the creation of the Finnish Register on Workers Exposed to Carcinogens (ASA Register) in 1979. Employers are obliged to provide data on the use of selected carcinogens and to provide information on exposed workers on an annual basis to the labour safety authorities (from 2006, directly to the Finnish Institute of Occupational Health (FIOH)) so that it can be entered into the database maintained by FIOH. It was anticipated that compulsory registration would stimulate identification, assessment and elimination of carcinogenic exposures in workplaces and result, thus, in a decreased risk of occupational cancer among monitored workers (Kauppinen *et al.*, 2007).

In 2010, the number of workers notified by employers to the ASA Register as having been exposed to selected carcinogens was about 16,000 (0.6% of the workforce). The most common exposures were to chromium VI compounds and nickel, followed by PAH and benzene. The proportion of the workforce exposed has decreased gradually since 2005, when smoking was prohibited in restaurants and bars. During the period 2001–5, the number of exposed workers each year was about 28,000, as a large number of waiters and other workers were exposed to environmental tobacco smoke (ETS). Another agent to which there is clearly decreasing exposure is asbestos, which was banned in Finland in 1994. The largest worker group exposed to asbestos used to be car mechanics (brake maintenance), but in 2010 exposure occurred mainly in conjunction with renovation works on old buildings which potentially contained asbestos (less than 1,000 exposed workers). The workers notified as having been exposed were usually men (80%). ASA registration does not cover such commonly occurring carcinogenic exposures as silica, diesel exhaust or radon (Saalo *et al.*, 2012).

The preventive effect of the ASA Register on cancer incidence among exposed workers has been studied (through a questionnaire-based survey and epidemiological cohort study, Kauppinen *et al.*, 2007). According to the results, changes to eliminate or at least substantially reduce exposure to carcinogens have been described by 73% of work departments that reported to ASA in 1996. The ASA notification process directly prompted measures to reduce exposure (8% of cases) or contributed to them (24% of cases). Estimates based on responses suggested that ASA decreased exposure by 600 workers per year (out of about 15,000 notified workers), thus preventing an unknown number of occupational cancers. Other benefits of ASA included saving the costs of treating the prevented cancers, the prevention of other health outcomes caused by the carcinogenic agents, improved safety behaviour of exposed workers and avoidance of human suffering for cancer patients and their families. Furthermore, the labour safety authorities were able to better target their activities against carcinogen exposure. These benefits should be considered against the annual personnel costs required to undertake the tasks related to ASA, considered to be, principally, 7–8 person-years[1] of work. The results of the cancer incidence study among notified workers were based on a relatively short follow-up period (on average 19 years). The incidence of mesothelioma was significantly higher than average in the ASA cohort, probably as a result of exposure to asbestos.

- **SIREP (Italy)**

The Italian Information System on Occupational Exposures to Carcinogens (SIREP) was founded in 1996 as a result of the implementation of European directives on the improvement of workplace safety and health. The following core data are collected in the system: enterprise characteristics, worker demographics and exposure information. Statistical descriptive analyses were performed by Scarselli *et al.* according to economic activity sector, carcinogenic agent and geographical location (Scarselli, Montaruli & Marinaccio, 2007). The SIREP database aims to assess, control and reduce carcinogenic risk in the workplace. It is expected to be useful also as part of surveillance and monitoring systems to identify the need for interventions and to assess their effectiveness.

The SIREP information system recorded about 37,000 workers exposed to selected carcinogens between 1996 and 2005; that is about 0.2% of the employed labour force in Italy. The most common exposures were hardwood dust (carpenters, furniture workers, and so on), PAHs (asphalt workers), chromium VI compounds (welders) and various chemicals to which chemical processing plant workers may have been exposed (for example benzene, butadiene, acrylonitrile, dichloroethane, vinyl chloride, ethylene oxide and propylene oxide) (Scarselli, Montaruli & Marinaccio, 2007).

SIREP also reports on mean exposure levels according to industrial hygiene measurements carried out in workplaces where exposure occurs. A separate publication based on the SIREP data reports on occupational exposure levels to wood dust. In the period 1996–2005, the mean concentration of wood dust in the air in the workplaces measured was 1.4 mg/m^3 (based on 10,837 measurements) (Scarselli *et al.*, 2008). In 2011, the data recorded covered the following: 12,300 firms, 130,000 workers and 250,000 exposures (Scarselli, 2011).

- **Poland – Central Register of CM agents**

The Central Register of Carcinogenic or Mutagenic Agents contains information received from all over the country on the basis of data from employers (Polish register of CM Agents). Data are reported to the sanitary Inspection once a year, and then transferred to the Central Register maintained (from 1999 onwards) by the Nofer Institute of Occupational Medicine (NIOM) in Lodz. Access to detailed information is available to the Chief Sanitary Inspector and the state regional (voivodeship) sanitary inspectors; district labour inspectors have access to the data appropriate for their area. Data from registers are also available to occupational physicians and physicians involved in recognition of occupational diseases.

[1] A person-year is defined as the amount of work done by an individual during a working year, on a specific job. The terms are used by companies to estimate the budget for projects or the impact of staff changes on specific tasks.

Access is also provided to workers in terms of information that concerns them personally, and workers' representatives in terms of anonymous collective information.

The legal basis requires employers to keep a register of tasks that involve exposures to a defined list of substances, mixtures, factors and technological processes. The list has been enlarged from 88 to 819 items in 2004 compared to the list of 1996. It includes five processes, two biological factors - hepatitis B and C and a physical agent - ionizing radiation (alpha, beta, gamma, neutron, and X-ray)

Data contained in the Central Register of Carcinogenic or Mutagenic Agents are regularly analysed and decribed in scientific articles published in "Medycyna Pracy" (texts are in Polish, with English abstracts). In 2008 – 2010 more than 300 carcinogenic or mutagenic chemical substances were reported to the register. Approximately 2,500 plants reported more than 150,000 per-person-exposures annually. Among all technological processes regarded as occupational carcinogens, hardwood dusts exposure (about 660 companies; 11,000–13,000 exposed workers per year) and exposure to polycyclic aromatic hydrocarbons (PAHs) present in coal products (117–125 plants, 3,000 exposed per year) were reported.

The most widespread carcinogenic/mutagenic substances were: benzene, Chromium(VI) compounds: potassium dichromate and chromate, chromium(VI) trioxide and other chromium compounds, ethylene oxide, asbestos, benzo[a]pyrene and gasoline. Among men, the highest numbers were exposed to particular PAHs and benzene, and the majority of women were exposed to benzene, potassium dichromate and chromate, acrylamide, ethylene oxide and gasoline. The lack of a clear-cut definition of occupational exposure to carcinogens makes it difficult for employers to define the accurate number of exposed workers (Koniecko *et al.*, 2013).

Other national registers on carcinogen exposure

Germany has collected information since 1987 on subjects who have been exposed to category 1 or 2 carcinogens (German categories) and are entitled to medical examinations because of their carcinogen exposure (Service for the Organisation of Post-Exposure Medical Examinations - Organisationsdienst für nachgehende Untersuchungen ODIN) register. The aim of ODIN is to deal with compensation for the costs incurred by such examinations. ODIN contains information about 50,000 exposed workers, but no detailed data about substances and sectors are publicly available. Germany also has a specific register of workers formerly exposed to asbestos (see Table 7).

The Czech Republic, Romania and Slovakia also have registers or databases on workers who have been exposed to carcinogens (see Table 7).

In Hungary, the authority responsible for occupational health and safety inspection collects data of workers exposed to carcinogenic substance(s). The legal basis is the 2005 modification of the Occupational Safety and Health Act. According to §83/A every employer is obliged to provide data on his/her workers exposed to occupational carcinogens. The dataset contains the employer's name, premise and sector; the worker´s year of birth, public health identifier, occupation, years in exposure related to the occupation. Data, which is stored for fifty years, is forwarded to the occupational health body in order to promote prevention measures and policy making. Currently a system that will process existing data and enable electronic data provision is under construction. Annex 3 of the Decree on the prevention of occupational carcinogens was added in 2009. It specifies datasets that have to be provided annually by the employer to the regional labour inspectorate. Besides the individual data discussed in the Occupational Safety and Health Act, the following summary data are required: substances used (including CAS number), characteristics of exposure (including workplace measurement data), ISCO codes and number of exposed workers, and the specific prevention measures applied.

Table 7: Description of major exposure information systems and reports dedicated to carcinogen exposure in the Member States of the European Union

Country/ Countries covered	Name/title of database	Access/Descriptiom
CZ	Register of occupational exposure to carcinogens: REGEX	The register currently contains 17,400 records on a total of 8,105 persons occupationally exposed to carcinogens. Provider: Institute of Health Information and Statistics
DE	ODIN (register of workers exposed to CMR requiring medical supervision)	Currently 50,000 exposed workers; no detailed info about substances and sectors publicly available. http://www.odin-info.de/index.php?selectedMenuId=thema_0
DE	GVS (register of asbestos-exposed workers)	Currently 510,000 formerly asbestos-exposed workers are registered. No detailed info about sectors and workplaces publicly available. http://gvs.bgetem.de/_0
EU (as of 1997)	CAREX database (International Information System on Occupational Exposure to Carcinogens)	CAREX calculates the number of exposed workers in 19 EU Member States. A common methodology is applied; the figures are partly from the 1980s and '90s. http://www.ttl.fi/en/chemical_safety/carex/pages/default.aspxhttp://www.ttl.fi/en/chemical_safety/carex/pages/default.aspx
FI	ASA (Register on Workers Exposed to Carcinogens)	The register contains about records of 80,000 workers, with 15,000 new notifications annually. Contact Ms Anja Saalo Anja.Saalo@ttl.fi
FR	CMR 2005	A representative sample of 2,000 companies, in 30 sectors, was used to estimate the annual consumption of 324 CMR chemicals and hundreds of petroleum derivatives. Information available athttp://www.inrs.fr/accueil/produits/mediatheque/doc/publications.html?refINRS=PR%2026
FR	AFSSET list of the 50 main reprotoxicants	The list compiles information from different databases and lists of substances that are potential reprotoxicants: a score related to exposure is established. http://www.afsset.fr/upload/bibliotheque/598265688036318549968130225990/31_valeurs_toxicologiques_reference_reprotox_avis_annexes_afsset.pdf See also: http://www.jle.com/e-docs/00/04/48/B3/article.phtml
FR	*Professional exposure to asbestos*, 2011	This report presents information on a measuring campaign carried out at 75 construction sites. Information available at http://www.inrs.fr/accueil/header/actualites/campagne-META.html

Country/ Countries covered	Name/title of database	Access/Descriptiom
IT	SIREP (Register of exposures to carcinogens)	SIREP was founded in 1996. It reports occupational exposures of approximately 36,500 employees from 2,778 firms, between 1996 and 2005. It is linked to SIRDE, a system for registration of exposures by companies. Information available at http://www.ispesl.it/dml/leo/RegSys.asp
PL	Central Register of Carcinogenic or Mutagenic Agents	The register contains reported data annually reported by enterprises to the sanitary inspection and transferred to the Central Register maintained (from 1999) by the Nofer Institute of Occupational Medicine (NIOM) in Lodz. Information available at: http://www.imp.lodz.pl/home_pl/o_instytucie/reg_and_databases/prof_and_env_carcenogenesi/
PL	Annual report of the Central Statistical Office (GUS)	The report contains data on working conditions collected under a programme of statistical surveys of public statistics. It covers employment in hazardous conditions, incl. carcinogens incl. dusts, and elimination or restriction, and occupational risk assessment. Information available at http://stat.gov.pl/files/gfx/portalinformacyjny/pl/defaultaktualnosci/5476/1/8/3/warunki_pracy_w_2013.pdf
RO	Registrul National Vizand Expunerea la Agenti Cancerigeni, part of the Registrul de Cancer database in Romania	The register (just started) contains information about the workplaces and the persons exposed. It is part of the general register for exposure to carcinogens. http://www.protectiamuncii.ro/en/ew2003/conferinta/materiale/04_prioritati_in_politica_de_prevenire_a_riscurilor_profesionale_cancerigene.pdf
SK	Databases of public health authorities (RPHA), register of employees exposed to carcinogens	The register contains records on total persons occupationally exposed to carcinogens.
UK	*Asbestos Survey 1971–2005*, UK, 2009	The report presents data on mortality among asbestos workers between 1971 and 2005 http://www.hse.gov.uk/research/rrpdf/rr730.pdf

Source: Kooperationsstelle Hamburg IFE (in press)

The numbers of workers reported as exposed in the national registers (ASA, SIREP) are far smaller than the numbers in exposure information systems where the estimates are based on expert judgements, which in turn may have been based on measurements or surveys (see Section 2.2.3). The main reasons for this are that national registers cover only selected carcinogens and that there is usually substantial underreporting in data collection systems which are based on notifications made by enterprises. In particular, low exposures and short-term exposures may remain unreported, whereas they may well be counted in estimate-based information systems, as described in Sections 2.2.3 and 2.2.4.

There are many process-generated substances, like hardwood dust, chromium- and nickel-containing fumes, PAHs and asbestos, which are covered by the registers. Two important cancer-causing substances that are also process-generated are quartz dust and diesel engine exhaust fumes and gas, but these are not yet covered by registers, mainly because of their very wide use range. In addition, exposures to radon or to UVR are not stipulated as needing to be notified to registers.

2.2.2. Exposure measurement databases

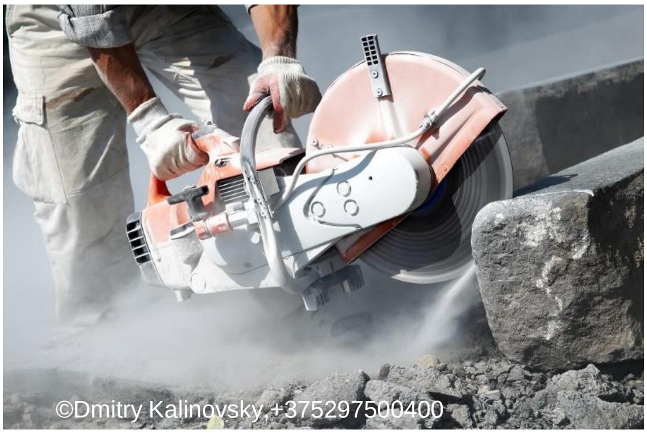
National databases on industrial hygiene measurements exist in many European and non-European countries (Vinzents *et al.*, 1995). Most of these include a substantial number of measurements on carcinogens in workroom air. Only some examples of these databases are described briefly here.

Many of the international and national databases on industrial hygiene measurements do not provide detailed results of individual measurements. Furthermore, the summary information reported is often limited. For example, the results included in the ExpoSYN database are not publicly available. The reason for this is usually the confidentiality of the data.

ExpoSYN

ExpoSYN is a measurement database which integrates data from 18 European countries and Canada on five lung carcinogens. In 2012, the database included a total of 356,551 measurement results. The measurements were distributed by agent as follows: respirable crystalline silica (42%), asbestos (20%), chromium (16%), nickel (15%) and PAHs (7%). The measurements cover a long period, from 1951 to present, but only a small portion of them (1%) were performed before 1975. Peters *et al.* noted in 2012 that ExpoSYN is intended to be used to build a job–exposure matrix (JEM) for a large pooled analysis of epidemiological case–control studies on lung cancer (SYNERGY study) (Peters *et al.*, 2012). The criteria for selecting asbestos, PAHs, nickel, chromium and respirable crystalline silica as the exposures of interest were:

- classification in IARC group 1 (carcinogenic to humans);
- prevalence of joint exposure in study populations;
- availability of quantitative exposure data;
- possibility to disentangle the effects of correlated occupational exposures;
- possibility to disentangle occupational exposures from exposures in general population;
- mechanistic considerations (shared or different modes of biological action);
- relevance for prevention;
- relevance for compensation



Stone cutting

MEGA (Germany)

IFA maintains a large database, Measurement Data on Exposure to Hazardous Substances in the Workplace (**MEGA**), on workplace measurements of chemical agents (data from 1962 onwards) and biological agents (data from 1998 onwards). The total number of measurement results is now around 2.5 million; they have been obtained from about 4,600 different workplaces and concern 840 different chemical agents and 540 biological agents (Gabriel, 2006; Koppisch *et al.*, 2012). Carcinogens are not listed separately in this database.

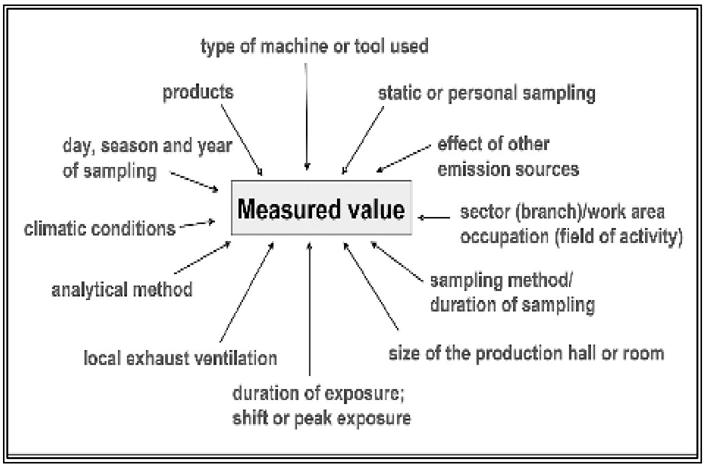
Many agent- and industry-specific reports summarising data from the German MEGA database have been published (MEGA database and publications), for example on welding, manual dismantling of electronic waste and the industrial use of hard metals. The measurements have been used also to set up standard exposure assessments for the management of carcinogenic substances under the German rules (*Verfahrens- und Stoffspezifische Kriterien*, or process- and substance-specific criteria).

Data are also used to supply occupational exposure assessments under REACH; these assessments should consider the physical state of the substance, the physical state of the product handled, vapour pressure for liquids, 'dustiness' for solids, the level of containment, presence or absence of local exhaust ventilation (LEV), the duration of the activity and what is done with the substance.

To fulfil these aims, the exposure data are linked to context data via the MGU system (the Measurement System for Exposure Assessment of the German Social Accident Insurance), formerly called BGMG (Gabriel, Koppisch & Range, 2010). The system is operated by the German statutory accident insurance institutions, which, in their supervisory role, carry out workplace measurements. The content and systematic structure of the system are developed by the accident insurers' Operating and Exposure Data Acquisition group and are based primarily on the results of European projects that compared exposure databases in the mid-1990s. These identified and defined 'core information' essential to describe and assess exposure (Rajan *et al.*, 1997). The data collection process has developed steadily over the decades. Starting with a dataset of about 30 items of information per measured value, as collected from 1972 to 1989, and expanding to about 150 items during the period from 1990 to 2000, the number of possible data fields that can be filled in has risen to over 200 (Gabriel, Koppisch & Range, 2010)(Figure 1). When conducting evaluations based on the exposure database MEGA, it is essential to be aware of the historical developments in data acquisition and bear these in mind in the interpretation of the data. This is why data are not openly accessible.

Statistical evaluations of exposures in connection with preventive measures are included, among other things, in EGU recommendations (recommendations from social security organisations for risk assessment) and are available to companies as an aid to risk assessment. Process- and substance-specific analyses of trends in exposure levels over time are also produced. Retrospective overviews of exposures in specific work areas are published in reports, for example on exposure to silica over time.

Figure 1: Exposure variables within MGU data acquisition



COLCHIC and SCOLA (France)

The French National Institute of Safety and Health (INRS) maintains the databases COLCHIC and SCOLA. They were inaugurated in 1987 and 2007 respectively. COLCHIC is concerned with industrial hygiene measurements of chemical agents made by INRS and eight regional health insurance funds (CRAMs). COLCHIC was set up in 1987, and in 2001 it included over 400,000 measurement results of exposure to 600 substances (Vincent and Jeandel, 2001). The data in COLCHIC cover 40 substances with more than 4,000 measurements from 48,607 sampling visits to 24,520 factories. Data in SCOLA cover 11 substances with more than 1,000 measurements from 33,075 sampling visits to 4,384 factories. COLCHIC has 830,000 records, whereas SCOLA has 119,000 records (Mater *et al.*, 2013). SCOLA was created to store data collected in the context of mandatory verification of compliance with legal occupational exposure limits (OELs) in France. Despite having different objectives, COLCHIC and SCOLA have the same structure. The ancillary information includes industry, occupation, task, local and general ventilation, representativeness and sampling strategies.

The five substances most frequently detailed in COLCHIC are respirable dust (62,876), toluene (31,766), acetone (28,763), lead (24,614) and xylene (21,768). The five substances most frequently detailed in SCOLA are asbestos (63,886), wood dust (12,625), crystalline silica (4,353), lead compounds, (3,135) some of which are carcinogens, and toluene (2,505). The main industrial activities mentioned in both databanks are manufacturing, construction, and waste management and remediation. The COLCHIC data for fibres (asbestos, ceramic fibres, and so on), formaldehyde and lead have been reported in French

INRS is currently revising COLCHIC and SCOLA in order to assess:

- how representative they are of historical exposures in France;
- how the different objectives of the databases may influence the choice of substances and exposure levels monitored.

NEDB (United Kingdom)

The Health and Safety Executive (HSE) is responsible for worker Health and Safety in the United Kingdom and maintains a United Kingdom National Exposure Database (NEDB). It includes information on the measurement of chemical agents carried out by the HSE since the mid-1980 (Burns & Beaumont, 1989). NEDB is not specifically a data source for occupational exposure to carcinogens. It is intended to be an institutional resource on the actually occurring levels of industrial exposures, and of the situations in which these levels can arise. NEDB has approximately 19,000 individual visit records on substances hazardous to health. The majority of visit records contain sampling data points. The number of sampling data points held in NEDB is about 1 million. The information relates to air concentration, breathing zone exposure levels and total exposure burden (contribution through inhalation, skin and ingestion) estimated using biological samples – exhaled breath, urine and/or blood as appropriate. NEDB does not store the names of individuals who were subjected to sampling. However, a given anonymised air sampling data can be linked to an individual's name through the original visit record held in HSE's internal electronic records system. The recorded information includes: occupier name and address, date of visit, industry, process and job, substances sampled and their concentration, sample type (breathing zone; static or biological) and exposure modifier information. HSE is currently reviewing the future of the NEDB.

IMIS (United States)

The largest US dataset of industrial hygiene measurements is the Integrated Management Information System (IMIS), which contains the results of measurements made by the safety inspectors of the US Occupational Safety and Health Administration (OSHA) since 1979. In 2010, a partially overlapping dataset of OSHA's central laboratory (Chemical Exposure Health Data (CEHD), over 1 million personal samples) has also become publicly available. The most frequently measured agent was inorganic lead (over 74,000 samples). Other agents with more than 1,000 samples and associated with cancer include benzene, tetrachloroethylene, trichloroethylene, beryllium, cadmium, chromium VI compounds, nickel, ethylene oxide, formaldehyde, vinyl chloride, PAHs, crystalline silica, asbestos and inorganic arsenic (Lavoué *et al.*, 2012). The IMIS exposure data can be obtained from OSHA by any citizen or organisation in accordance with the Freedom of Information Act. Data are available by request and for a processing fee (Lavoué, Friesen & Burstyn, 2013).

Other sources of measurement data

In addition to international and national measurement databases, there are many other datasets that include measurements on carcinogens. The results of these measurements have been reported in numerous scientific and other articles. Many industrial hygiene datasets have been analysed to assess variability in exposures (Kromhout, Symanski & Rappaport, 1993) and to examine changes in exposure levels over time (Creely *et al.*, 2007). The results about carcinogen exposure from these measurement databases, and those from numerous other scientific publications, are not presented here, as this would be beyond the scope of this review.

2.2.3. Information systems on carcinogen exposure

Introduction to CAREX

The International Information System on Occupational Exposure to Carcinogens (CAREX) was set up in the mid-1990s, and it includes estimates of exposure prevalence and numbers of exposed workers in 55 industries for 15 Member States of the EU in 1990–3 (Kauppinen *et al.*, 2000). The major use of CAREX has been in hazard surveillance and risk/burden assessment. It has been updated with exposure level estimates in Finland (CAREX Finland, FIOH 2013a; reported only in Finnish), in Italy (Mirabelli & Kauppinen, 2005) and in Spain. New countries have been added to CAREX (Estonia, Latvia, Lithuania and the Czech Republic) (Kauppinen *et al.*, 2001) and it has been extended to Costa Rica, Panama and Nicaragua (Partanen *et al.*, 2003; Blanco-Romero, Vega & Lozano-Chavarria, 2011). It has been modified for wood dust (WOODEX), with exposure level estimates for the 25 Member States of the EU (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 in estimating the burden of occupational cancer in the United Kingdom (Rushton, Hutchings & Brown, 2008); it has been used also by other Member States of the EU (SHEcan project, see Section 4.2.1). The most widely developed model at the moment is probably CAREX Canada, which disseminates information on exposures and risks through an informative, easy-to-use and free-of-charge web application. In addition CAREX Canada intends to identify appropriate measures to prevent occupational cancer risks in practice. More details are given below.

CAREX includes data on agents which have been evaluated by the IARC (all agents in groups 1 and 2A as of February 1995, and selected agents in group 2B) and on ionising radiation.

The occupational exposures were estimated in two phases.

The estimates were first generated by the CAREX system on the basis of national labour force data and exposure prevalence estimates from the two reference countries (Finland and the United States) for which the most comprehensive data were available on exposures to these agents.
For selected countries, these estimates (default values) were then refined by national experts, taking into consideration the exposure patterns in their own countries compared with those of the reference countries. The numbers of exposed workers were reported by country, carcinogen and industry, but the levels of exposure were not estimated (Kauppinen *et al.*, 2000).

The same procedure, with refinement by national experts, was applied when estimates were generated for Estonia, Latvia, Lithuania and the Czech Republic for the year 1997 (Kauppinen *et al.*, 2001) and updated for Italy for 2000–3 (Mirabelli & Kauppinen, 2005). Some CAREX exposure data for the United Kingdom have also been re-evaluated and updated (Cherrie, van Tongeren & Semple, 2007).

CAREX EU-15

The CAREX system, which first examined exposures in 15 European countries about 20 years ago, is still the most comprehensive information system on carcinogen exposures in Europe. In 1990–3, about 32 million workers in the EU (23% of those employed) were exposed to agents covered by CAREX. The numbers of exposed workers are presented by country in Table 8. The countries with a large labour force dominate these figures, but the economic structure of the country and the exposure circumstances also influence the prevalence of exposure. It is worth noting that all the figures in CAREX reflect the situation in the early 1990s and many estimates are already outdated. This is not only because of changes in the structure of the labour force. Exposure to ETS, for example, has decreased considerably because of new regulations prohibiting or restricting smoking at work and in restaurants and bars.

Table 8: Numbers of workers (in thousands) exposed to agents covered in the CAREX project in 15 Member States of the European Union by country and by selected agents in 1990–3

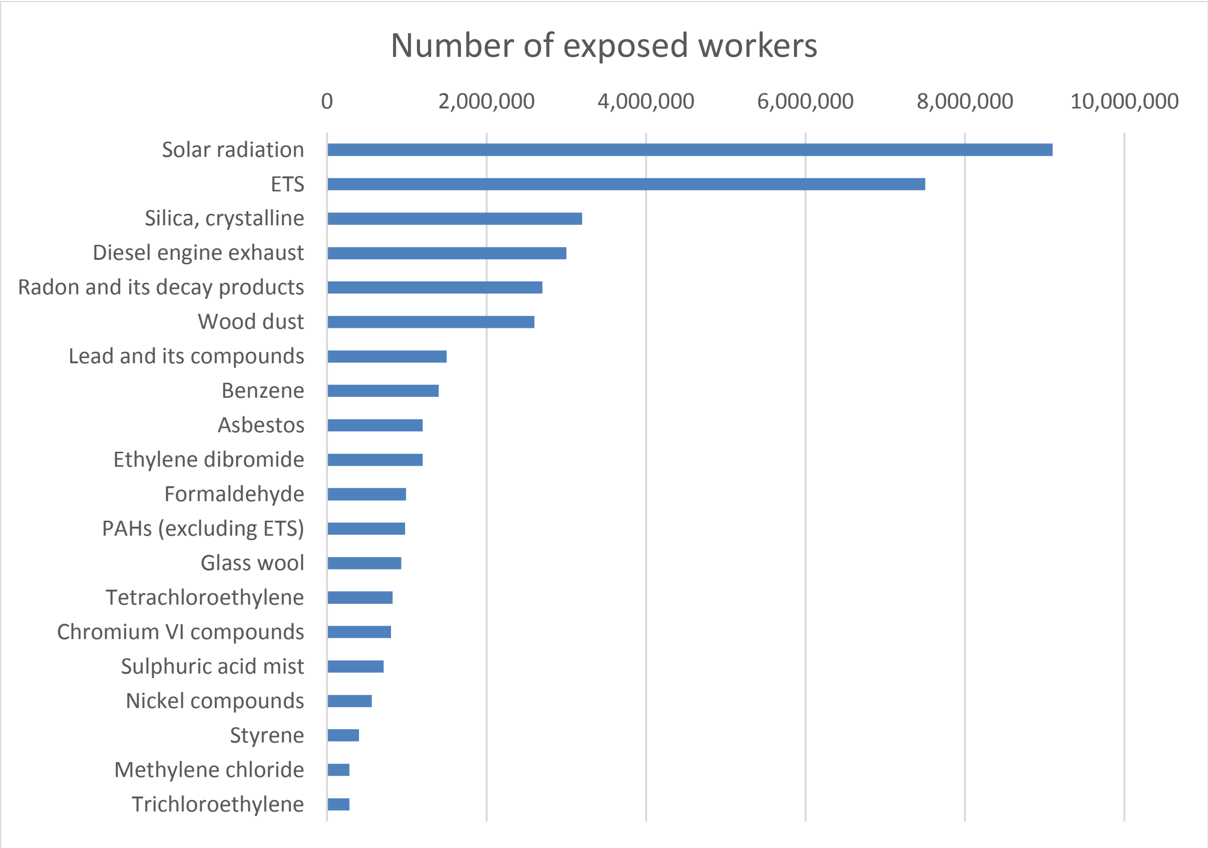
Country	Total	% of the employed	Solar radiation	ETS	Crystal-line silica	Diesel exhaust	Radon
Austria	790	25	240	180	100	79	72
Belgium	730	21	200	190	74	67	86
Germany	8,300	24	2,400	2,000	1,000	720	820
Denmark	680	24	180	199	59	71	0
Spain	3,100	25	1,100	670	400	270	280
France	4,900	23	1,500	1,200	110	410	520
Finland	510	24	180	110	83	39	49
United Kingdom	5,000	22	1,300	1,300	590	470	560
Greece	910	27	460	170	87	79	66
Italy	4,200	24	560	770	280	550	38
Ireland	260	24	110	58	29	21	24
Luxembourg	48	25	14	11	7	4	4
Netherlands	1,100	17	290	350	170	110	0
Portugal	970	24	370	210	83	73	92
Sweden	820	20	240	210	86	81	99
EU-15	**32,318**	**23**	**9,100**	**7,500**	**3,200**	**3,100**	**2,700**

Source: Kauppinen *et al.*, 2000

The CAREX agents to which the largest numbers of workers were exposed are presented in Figure 2. The full list of CAREX agents is presented in Table 9. At least 22 million workers were exposed to IARC group 1 carcinogens. The exposed workers had a total of 42 million exposures (a worker could be exposed to multiple agents; on average approximately 1.3 exposures per exposed worker). The most common exposures were solar radiation (9.1 million workers exposed during at least 75% of their working time), ETS (7.5 million workers exposed during at least 75% of their working time), crystalline silica (3.2 million exposed), diesel exhaust (3.0 million), radon (2.7 million) and wood dust (2.6 million).

Street maintenance worker

Figure 2: Most common agents covered by CAREX to which workers were exposed (numbers of exposed workers) in 15 Member States of the European Union in 1990–3



Source: Kauppinen *et al.*, 2000.

Table 9: Numbers of exposures by agent (in thousands) in 15 Member States of the European Union in 1990–3 for all agents covered by CAREX

Agent	Number of exposures [a]	IARC group	Comment
Acrylamide	31	2A	
Acrylonitrile	32	2B[b]	
Adriamycin (Doxorubicin)	18	2A	used in cancer therapy
Aflatoxins	2	1	
4-aminobiphenyl	0	1	
Arsenic and arsenic compounds	150	1	
Asbestos	1,200	1	
Azacitidine	1	2A	used in cancer therapy
Azathioprine	2	1	immunosuppressive drug
Benzene	1,400	1	
Benzidine	7	1	
Benzidine-based dyes	14	1[c]	
Beryllium and beryllium compounds	67	1	
Bis(chloroethyl) nitrosourea (BCNU, Carmustin)	10	2A	used in cancer therapy
Bis(chloromethyl) ether (BCME)	2	1	
1,3-butadiene	32	1[c]	
1,4-butanediol dimethanesulfonate (Myleran, Busulfan)*	3	1	used in cancer therapy
Cadmium and cadmium compounds	210	1	
Captafol	8	2A	used as pesticide
Carbon tetrachloride	75	2B	
Ceramic fibres	62	2B	
Chlorambucil	10	1	used in cancer therapy
Chloramphenicol	12	2A	antibiotic

Agent	Number of exposures [a]	IARC group	Comment
1-(2-chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU, Lomustine)	2	2A	used in cancer therapy
Chlorozotocin	< 1	2A	used in cancer therapy
p-chloro-o-toluidine and its strong acid salts	1	2A	
Chromium VI compounds	800	1	
Cisplatin	25	2A	used in cancer therapy
Cobalt and its compounds	240	2B	
Cyclophosphamide	45	1	used to treat cancers and autoimmune disorders
Cyclosporine	10	1	immunosuppressive drug
Diesel engine exhaust	3,000	1[d]	
Diethylstilbestrol	< 1	1	drug
Diethyl sulfate	2	2A	
Dimethylcarbamoyl chloride	0	2A	
Dimethyl sulfate	10	2A	
Epichlorohydrin	48	2A	
Ethylene dibromide	1,200	2A	
Ethylene oxide	47	1	
N-Ethyl-N-nitrosourea (ENU)	0	2A	
Formaldehyde	990	1[c]	
Glass wool	930	2B	
Hepatitis B virus	Not estimated	1	
Hepatitis C virus	Not estimated	1	
Ionising radiation	150	1[e]	
Lead and inorganic lead compounds	1,500	2A[f]	
Melphalan	10	1	used in cancer treatment
Methyl-CCNU (Semustine) 1-(2-Chloroethyl)-3-(4-methyl-cyclohexyl)-1-nitrosourea	< 1	1	used in cancer treatment

Agent	Number of exposures [a]	IARC group	Comment
N-methyl-N-nitrosourea	0	2A	
4,4′-Methylene-bis(2-chloroaniline) (MOCA)	3	1[c]	
Methylene chloride	280	2B	
N-Methyl-N´-nitronitroso-guanidine (MNNG)	1	2A	
Mustard gas (sulphur mustard)	1	1	
2-Naphthylamine	2	1	
Nickel compounds	560	1	
Nitrogen mustard	3	2A	
N-Nitrosodiethylamine	13	2A	
N-nitrosodimethylamine	14	2A	
Oestrogens, nonsteroidal	5	1	
Oestrogens, steroidal	5	1	
Oral contraceptives, combined	5	1	
Oral contraceptives, sequential	5	1	
Pentachlorophenol	49	2B	
Phenacetin	3	1[c]	Pain-relieving and fever-reducing drug
Polychlorinated biphenyls (PCB)	15	1[g]	
Polycyclic aromatic hydrocarbons (PAH)	980	1–3	
Procarbazine hydrochloride	<1	2A	
Radon and its decay products	2,700	1	
Silica, crystalline	3,200	1[h]	
Solar radiation (at least 75% of working time)	9,100	1	
Styrene	400	2B	
Styrene-7,8-oxide	86	2A	

Agent	Number of exposures [a]	IARC group	Comment
Sulphuric acid mist	710	1	
Talc containing asbestiform fibres	28	1	
Tetrachloroethylene (perchloroethylene)	820	2A	
Thiotepa	3	1	used in cancer treatment
Tobacco smoke (ETS) (at least 75% of working time)	7,500	1	
Treosulfan	0	1	used in cancer treatment
Trichloroethylene	280	1	
1,2,3-Trichloropropane	1	2A	
Tris(2,3-dibromopropyl) phosphate	< 1	2A	
Vinyl bromide	0	2A	
Vinyl chloride	40	1	
Vinyl fluoride	0	2A	
Wood dust	2,600	1	
Total	**42,000**	–	

[a] Exposure refers to one exposure to one worker
[b] Re-evaluated in 1999 (from group 2A)
[c] Re-evaluated in 2012 (from group 2A)
[d] Re-evaluated in 2013 (from group 2A)
[e] Re-evaluated in 2012
[f] Re-evaluated in 2006 (from group 2 B)
[g] Re-evaluation in preparation (from group 2A)
[h] Re-evaluation of occupational exposure 1997 (from group 2A)
Source: Kauppinen *et al.*, 2000, updated to IARC classification as of October 2014

Table 10 presents the CAREX results subdivided by industry. The industries with the highest numbers of exposed workers are construction (6.1 million workers exposed to crystalline silica, solar radiation, wood dust, diesel exhaust, asbestos, and so on), agriculture and hunting (3 million workers exposed to solar radiation and so on), wholesale and retail, and restaurants (3.5 million workers exposed to ETS, solar radiation, and so on), land transport (1.7 million workers exposed to diesel exhaust, solar radiation, and so on), personal and household services, including car servicing (i.e. car repairs and maintenance) (1.6 million workers exposed to petrol-based benzene and ethylene dibromide, ETS, lead, and so on). Exposure to ethylene dibromide and lead has decreased significantly since 1990–3 as a result of the decline in use of leaded petrol. A significant reduction in occupational exposures has occurred also for ETS in working environments where tobacco smoke was common (such as restaurants).

Table 10: Numbers of employed, exposures and exposed workers (in thousands) in 15 Member States of the European Union by industry in 1990–3

ISIC[a] Rev. 2 code	Industry	Number of employed In 1,000s	Number of exposures[b]	Number of exposed workers
11	Agriculture and hunting	7,900	3,000	3,000
12	Forestry and logging	410	560	350
13	Fishing	230	150	150
21	Coal mining	370	1	1
22	Crude petroleum and natural gas production	130	43	43
23	Metal ore mining	62	150	29
29	Other mining	270	450	190
311–312	Food manufacturing	2,700	330	310
313	Beverage industries	410	59	59
314	Tobacco manufacture	88	4	4
321	Manufacture of textiles	1,300	240	220
322	Manufacture of wearing apparel	1,500	350	340
323	Manufacture of leather and products of leather	180	41	40
324	Manufacture of footwear	460	89	88
331	Manufacture of wood and wood and cork products	770	620	500
332	Manufacture of furniture and fixtures	790	810	600
341	Manufacture of paper and paper products	730	170	140
342	Printing, publishing and allied industries	1,700	450	440
351	Manufacture of industrial chemicals	1,000	460	350
352	Manufacture of other chemical products	950	380	340
353	Petroleum refineries	130	85	74
354	Manufacture of petroleum and coal products	26	18	18
355	Manufacture of rubber products	380	140	140
356	Manufacture of plastic products	840	380	330
361	Manufacture of pottery, china and earthenware	260	250	170
362	Manufacture of glass and glass products	300	200	130
369	Manufacture of other non-metallic mineral products	640	530	430
371	Iron and steel basic industries	850	560	380
372	Non-ferrous metal basic industries	360	230	160
381	Manufacture of fabricated metal products	2,800	1,300	810
382	Manufacture of machinery except electrical	3,800	1,200	830

ISIC[a] Rev. 2 code	Industry	Number of employed In 1,000s	Number of exposures[b]	Number of exposed workers
383	Manufacture of electrical machinery	3,000	470	440
384	Manufacture of transport equipment	3,000	1,500	970
385	Manufacture of instruments, etc.	540	200	190
39	Other manufacturing industries	400	120	110
41	Electricity, gas and steam	1,200	480	430
42	Water works and supply	220	84	84
5	Construction	11,000	9,000	6,100
6	Wholesale and retail trade and restaurants	24,000	4,200	3,500
711	Land transport	4,200	1,900	1,700
712	Water transport	350	250	180
713	Air transport	450	330	290
719	Services allied to transport	1,400	630	580
72	Communication	2,600	610	590
8	Financing, insurance, real estate, business services	13,000	1,100	1,100
91	Public administration and defence	11,000	1,600	1,600
92	Sanitary and similar services	1,400	430	360
931	Education services	9,000	370	330
932	Research and scientific institutes	490	140	100
933	Medical, dental and other health services	8,200	810	730
934	Welfare institutions	4,000	220	210
935–939	Business, professional and other organisations	1,500	230	230
94	Recreational and cultural services	2,100	280	270
95	Personal and household services	32,000	3,800	1,600
96	International organisations	160	1	1
	Total	**139,000**	42,000	32,000

[a] ISIC (International Standard Industrial Classification of all Economic Activities) is a United Nations system for classifying economic data. The Statistical Classification of Economic Activities in the European Community (NACE) is a system of classification derived from ISIC: categories at all levels of NACE are defined as either identical to or to forming subsets of single ISIC categories.

[b] The term 'exposure' in this column refers to one carcinogen exposure of one worker. If a worker is exposed to two CAREX carcinogens, the number of exposures is two but the number of exposed workers is one.

Source: Kauppinen *et al.*, 2000

The above results are for 15 Member States of the EU. The CAREX procedure was extended to Estonia, Latvia, Lithuania and the Czech Republic in 1997. According to the results, the numbers of workers exposed to carcinogens covered by CAREX in 1997 were about 180,000 (29% of the employed) in Estonia, 260,000 (28%) in Latvia, 470,000 (28%) in Lithuania and 1,400,000 (28%) in the Czech Republic. The most common exposures were to solar radiation (7–13% exposed at least 75% of working time), ETS (4–5% exposed at least 75% of working time), wood dust (3–5% exposed), crystalline silica (2–3% exposed), diesel exhaust (2–3% exposed), radon and its decay products (2% exposed), benzene (0.9–1.7% exposed), and lead and inorganic lead compounds (0.8–1.4% exposed). Exposure to asbestos was slightly less prevalent (0.3–1.1% exposed) (Kauppinen *et al.*, 2001).

CAREX Finland

A measure of levels of occupational exposure to carcinogens was incorporated into the updated estimates of CAREX Finland for 2000. CAREX Finland provides estimates of numbers of workers exposed in 2000, subdivided by level of exposure (classes: < 10%, 10–50% and >50% of the Finnish exposure limit), for 151 physical or chemical carcinogens (including the substances covered by CAREX and ASA) and for 95 industrial classes (NACE revision 1). CAREX's updated research in 2000 included all sectors and all the employed. The division of the exposed workers into exposure classes was based on the assumption that exposure would be log-normally distributed among the exposed workers within the same industry. The geometric or arithmetic mean value (GM or AM) of the distribution was derived from industrial hygiene measurements, and the width of the distribution (geometric standard deviation, GSD) was assumed to be 2.5, unless some other value was available from the measurement data. The estimates were region-specific and arrived at in collaboration with regional labour safety inspectors familiar with working conditions in the workplaces.

The specific aim of CAREX Finland was to identify industries where significant exposure to carcinogens would be likely to occur, thus enabling the local labour safety authorities to focus their advisory and control activities on high-risk workplaces.

CAREX Italy

Italy has updated its CAREX estimates for the period 2000–3. Changes in the labour force and exposure patterns since 1990–3 were taken into account (for the 1990–3 figures, see Table 8: Numbers of workers (in thousands) exposed to agents covered in the CAREX project in 15 Member States of the European Union by country and by selected agents in 1990–3

The most common exposures were to ETS (800,000), solar radiation (700,000), diesel exhaust (500,000), wood dust (280,000), silica (250,000), lead (230,000), benzene (180,000) and chromium VI (160,000) (Mirabelli & Kauppinen, 2005).

Use of CAREX data in the UK

A review by IOM in the UK based on CAREX UK data resulted in an estimate that almost 7 million people were exposed to 64 carcinogenic agents or circumstances. Estimates of prevalence were available for a small number of carcinogens from HSE reviews of hazardous substances or from other official sources. These data were compared with the corresponding CAREX data. The CAREX data were generally higher than the comparable data with respect to the numbers of people exposed available from the HSE. However, in selected cases there was also underestimation of the exposure prevalence when using the CAREX database. Information about the level of exposure to chemical agents was obtained from the NEDB and it was incorporated into the estimates of the prevalence of exposure (Cherrie, van Tongeren & Semple, 2007).

The HSE has recently initiated a CAREX GB project which aims to create, populate, and maintain, through ongoing updates, a database that can capture the prevalence and intensity of occupational exposures to carcinogens in GB.

A limitation of the current CAREX database is it does not differentiate between different levels of exposure even at a very basic level. For most carcinogens the risk of cancer is assumed to be approximately linear in terms of cumulative exposure and even limited exposure may lead to an increased risk of disease and there may be considerable variation in exposure between different industries.

The revised CAREX GB will aim to at least differentiate between workers in an industry who are not exposed and those exposed at low or high levels. This process should also consider the typical frequency of exposure and length of work in the industry, in addition to the intensity of exposure. This work is at a very early stage of development.

CAREX – non-EU countries

The CAREX approach to estimating the extent of exposure to carcinogens has prompted the construction of exposure information systems outside the Member States of the EU. Throughout the world, and especially in developing countries, occupational exposure to pesticides and carcinogens is responsible for a high number of fatalities, intoxications, cancers and other health outcomes every year. Effective prevention of these risks requires knowledge that and how exposure typically occurs. However, unfortunately, accurate information on exposure is seldom available, particularly in the developing countries.

An adaptation of CAREX called TICAREX was constructed in Costa Rica. The industry-specific prevalence of occupational exposures to 27 carcinogens and 7 groups of pesticides was assessed by Costa Rican experts, who had extensive experience of the national exposure circumstances. The distribution of the labour force by industrial sector was estimated on the basis of census data. Whenever the prevalence could not be assessed, the value from some other country with data was used as such or as modified by the Costa Rican experts. New features of TICAREX compared with CAREX are separate estimates for men and women, and the generation of credible low and high estimates of the numbers of workers exposed (Partanen *et al.*, 2003). In addition, the adaptations created in Nicaragua and Panama also provide gender-specific estimates of exposure (Blanco-Romero, Vega & Lozano-Chavarria, 2011).

According to the above-mentioned versions of CAREX, the proportions of exposed individuals were roughly at the same level in Nicaragua and Panama as in the EU. Only for benzene, hexavalent chromium, diesel engine emissions and solar radiation were the proportions of those exposed higher in these countries than in the EU.

The most common carcinogen exposures among the 1.3 million exposed workers were to solar radiation (333,000 exposed at least 75% of working time), diesel engine exhaust (278,000 exposed), and ETS (71,000). The most common pesticides were paraquat and diquat (175,000), mancozeb, maneb and zineb (49,000) and chlorothalonil (38,000). The numbers of those exposed were estimated separately for men and women. For the majority of agents studied, with the exception of ethylene oxide, the number of exposed men exceeded the number of exposed women. The most common exposures experienced by women were diesel engine exhaust (82,800 exposed), solar radiation (33,300 exposed) and ETS (23,600) (Partanen *et al.*, 2003).

In Nicaragua (where the situation in 2007 was examined) and Panama (where the situation in 2006 was examined), the most common exposures proved to be the same as in Costa Rica: solar radiation and diesel exhaust (over 9% of the labour force were exposed to these agents). A high proportion of exposure was also found for ETS in Panama and for some groups of pesticides in Nicaragua.

CAREX Canada

CAREX Canada is a national surveillance system which provides estimates on occupational and environmental exposure to substances associated with cancer. The aim of CAREX Canada is to provide data that will enable exposure reduction strategies and cancer prevention programmes to be better targeted and promote prevention at the workplaces.

CAREX Canada contains information profiles on over 70 carcinogens, estimates of occupational exposure for over 40 agents and estimates of environmental exposure for over 30 agents (as of June 2013).

Estimates of exposed workers are given by region and industrial class. Information is collected on all commonly occurring carcinogens covered by the EU CAREX system. Some pesticides (for example 2,4-dichlorophenoxyacetic acid (2,4-D), chlorothalonil dichlorvos, lindane, 2-methyl-4-chlorophenoxyacetic acid (MCPA), pentachlorophenol), physical exposures (for example ionising radiation, magnetic fields, artificial UVR) and other factors (for example shift work) are also included. The most common exposures are presented in Table 11 and Table 12).

National estimates of exposed workers are also provided by industrial class and level of exposure (low, moderate, high) (Peters *et al.* 2014). The methods of assessment and the definitions of exposure classes are clearly reported in a dedicated website (CAREX Canada Website), which includes training videos and tutorials, as well as a risk assessment tool (eRisk) for environmental exposures. An occupational exposure tool (eWork) is forthcoming, and it will show data by carcinogen, region, industry, occupation, gender and level of exposure.

Table 11: The most common exposures by agent or factor in Canada

Agent[a]	Number of exposed (in thousands)	% men	Main occupations/sectors
Shift work (regular night work or rotating shift schedule)	1,900	Varying by sector	Manufacturing (419, 20% of the workers in this sector) Trade (382, 16%) Health and social care (284, 18%) Accommodation and food services (247, 23%) Public administration (98)
Solar radiation	1,500	82	Farmers and farm managers (150), construction trades helpers (125), landscaping and ground maintenance labourers (115).
Diesel exhaust	781	92	Truck drivers (305), heavy equipment operators (83) bus and subway drivers (79), couriers, taxi drivers and firefighters.
Crystalline silica	380	93	Construction trades labourers (105), heavy equipment operators (41), plasterers and drywallers (34).
Benzene	375	88	Delivery and courier drivers (51), taxi and limousine drivers (38), firefighters (27), motor vehicle body repairers, material handlers, truck drivers and welders.
Wood dust	340	93	Carpenters (157), cabinetmakers, wood and pulp and paper industries, furniture finishers, chainsaw operators
PAHs	307	74	Chefs and cooks (71 (men) 52 (women)), cooking of foods, exposure for those who work in kitchens, mechanics, firefighters and gas station attendants, cashiers (at food establishments or gas stations), other food establishment workers

Agent[a]	Number of exposed (in thousands)	% men	Main occupations/sectors
Lead and lead compounds	277	90	For men, welders (77), police officers (34) auto mechanics, plumbers and pipefitters For women, police officers (6,700 exposed) and vocational instructors (4,200 exposed), welders and electronics assemblers
Asbestos	152	[b]	Carpenters and cabinetmakers (exposed during renovations; 34), construction trades helpers (28), electricians, plumbers, plaster and drywall installers, auto mechanics, and ship and boat building and remediation work (which is captured under remediation and waste management, and also under scientific and consulting services, for a total of 2,300 workers)
Formaldehyde	152	66	For men, wood product manufacturing workers (use of formaldehyde-containing resins & glues) For women, work in hospitals, schools and clothing manufacturing
UVR (artificial)	141	78	Welders (87), medical laboratory technologists and pathologists' assistants (6.4) and sheet metal workers (exposed via welding or proximity to welding, 5.3); the majority of workers in welding are male (96%), the majority in tanning salons and hospitals are female (87% and 83%, respectively)
Nickel	117	91	Welders (51), machine tool operators (12) construction millwrights and industrial mechanics (7.6), mechanics, dental technologists, and painters and coaters.
Chromium VI	104	92	Welders (20,000 men and 800 women), during the welding of stainless steel Significant variation in job titles of exposed persons by gender: women, dental technologists and technicians, printing machine and press operators (1,600 women exposed in each industry); men, welders, machinists, and automotive technicians
Styrene	89	84	Service technicians (20), plastics processing machine operators (7.8), furniture finishers and refinishers (6.2)

[a] Occupational exposures to ETS, radon and magnetic fields have not yet been estimated

[b] Primarily male

Source: CAREX Canada website, accessed June 2014 (see http://www.carexcanada.ca/en/)

Table 12: Exposure to known and suspected carcinogens by exposure level, Canada, 2006

CAREX agent	High exposure (n) (%)	Moderate exposure (n) (%)	Low exposure (n) (%)	Total
Shift work	1,900,000 (100%)*	–	–	**1,900,000**
Solar radiation	896,000 (61%)	391,000 (26%)	190,000 (13%)	**1,476,000**
Silica (crystalline)	53,000 (14%)	147,000 (39%)	182,000 (48%)	**382,000**
Benzene	1,400 (<1%)	32,000 (9%)	341,000 (91%)	**374,000**
Wood dust	93,000 (28%)	166,000 (49%)	79,000 (23%)	**338,000**
Lead	60,000 (22%)	81,000 (29%)	136,000 (49%)	**277,000**
Formaldehyde	3,700 (2%)	46,000 (30%)	102,000 (68%)	**151,000**
Ultraviolet radiation (artificial sources)	87,000 (62%)	34,000 (24%)	20,000 (14%)	**141,000**
Nickel	8,100 (7%)	12,000 (10%)	97,000 (83%)	**117,000**
Chromium (hexavalent) compounds	500 (<1%)	13,000 (12%)	90,000 (87%)	**104,000**
Styrene	38,000 (43%)	28,000 (32%)	23,000 (26%)	**89,000**
Ionising radiation†	<100	10,000–18,000	26,000–60,000	**36,000–78,000**
Antineoplastic agents	5,000 (9%)	40,000 (70%)	13,000 (21%)	**58,000**
Cobalt	1,800 (6%)	9,500 (29%)	21,000 (65%)	**33,000**
Cadmium	2,200 (7%)	21,000 (66%)	8,300 (27%)	**31,000**
Dichloromethane (methylene chloride)	3,400 (13%)	8,300 (33%)	14,000 (54%)	**25,000**
Tetrachloroethylene	700 (5%)	2,200 (15%)	12,000 (80%)	**15,000**

CAREX agent	High exposure (n) (%)	Moderate exposure (n) (%)	Low exposure (n) (%)	Total
Trichloroethylene	300 (3%)	5,400 (55%)	4,100 (42%)	**9,800**

*Only those working regular night and rotating night shifts are reported as exposed.

†Results presented as a range due to the assumption that fewer workers are monitored for ionising radiation exposure than are actually exposed; see methods section for more details.

Source: Peters *et al.* 2014

CAREX Canada was one of the sources used in estimating occupational exposure to carcinogens in the Quebec region in an interinstitutional project lead by the Quebec- based IRSST, a research institute under social partner governance, with the aim of raising awareness of occupational cancer and promoting prevention. CAREX data were used together with workplace monitoring data, research projects, a population survey, radiation protection data and published exposure data. These proportions were applied to Quebec labour force data. Among the 38 studied, the carcinogens to which the largest proportions of workers were exposed were solar radiation (6.6% of workers), night shift work/rotating shift work including nights (6.0%), diesel exhaust fumes (4.4%), wood dust (2.9%) and PAHs (2.0%).

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More than 15 carcinogens were identified in several industrial sectors, and up to 100,000 young workers were employed in these sectors (Labrèche *et al.*, 2013).

Over the next years, CAREX Canada will undertake a knowledge transfer programme to make CAREX information available and accessible to Canada's cancer prevention experts and policymakers. By 2017, CAREX Canada aims to

- Train and build capacity among stakeholders to use carcinogen exposure estimates for the purpose of evidence-based cancer prevention policy and practice.
- Design web-based tools to facilitate the use of carcinogen exposure data.
- Expand the network of stakeholders to include a wider range of users.
- Maintain data credibility and relevancy.
- Evaluate knowledge translation initiatives, activities and data tools.

2.2.4. *Other information systems including estimates on occupational exposure to carcinogens*

Example results on occupational exposure to carcinogens originating from national data systems covering a large spectrum of agents are shown in this section. The first example is the Finnish Job–Exposure Matrix (FINJEM) (Kauppinen, Toikkanen & Pukkala, 1998). The figures presented in Table 13 are summed from over 311 occupations.

The Finnish Job–Exposure Matrix (FINJEM)

One example of a database which covers a large selection of different exposures but includes also estimates on carcinogen exposure is the Finnish information system on occupational exposure **FINJEM** (Kauppinen *et al.*, 1998).

FINJEM provides quantitative estimates of the prevalence and level of exposure for over 80 chemical, physical, microbiological, ergonomic and psychosocial factors by occupation (n = 311) in eight time periods (1945–2009). FINJEM provides estimates of numbers of workers exposed to chemical agents by the level of exposure (classes: < 10%, 10–50 % and > 50% of the Finnish exposure limit).

The division of the exposed workers into exposure classes was based on the assumption that exposure would be log-normally distributed among the exposed workers within the same occupation and on industrial hygiene measurements or expert judgement. The major use of FINJEM has been as an exposure assessment tool in occupational epidemiology. For example, about 40 peer-reviewed articles on cancer, heart disease and other health outcomes in Finland and other countries have been published. FINJEM is updated every three years and used regularly for hazard surveillance in Finland. It provides information on agent-specific exposure trends, numbers of exposed workers and their exposure level distributions. In addition, future exposures can be predicted up to 2020 (see Section 3.1.1). The recent and future burdens of work-related fatalities and diseases have been studied using FINJEM data on exposures.

Table 13: Summary information on occupational exposure to agents associated with cancer in Finland in 2007–9

Agent or stress factor	Number of exposed	% of the employed	Mean level of exposure among the exposed
UVR	180,000	8	160 J/m^2
Low-frequency magnetic fields	500,000	24	0.4 µT
Ionising radiation	5,000	0.2	1.3 mSv
Formaldehyde	10,000	0.4	0.1 ppm
Benzene	2,000	0.1	0.1 ppm
Trichloroethylene	3,000	0.1	5 ppm
Wood dust	56,000	2	0.6 mg/m^3
Asbestos	4,000	0.2	0.04 fibres/cm^3
Quartz dust (crystalline silica)	52,000	2	0.06 mg/m^3
Cadmium	1,000	< 0.1	1.3 µg/m^3
Chromium	25,000	1.1	5 µg/m^3
Lead	7,000	0.3	0.4 µmol/l
Nickel	32,000	1.4	6 µg/m^3

Agent or stress factor	Number of exposed	% of the employed	Mean level of exposure among the exposed
Arsenic	1,000	< 0.1	2 µg/m^3
ETS at work	3,000	0.1	84% of time
Diesel exhaust	54,000	2	0.14 mg/m^3 NO_2
PAH	8,000	0.3	3.2 µg/m^3
Night work (in 1985–94)	600,000	29	*

* The level of night work is not assessed

Source: FINJEM database (FIOH, 2013b)

FINJEM has also proved to be useful in the construction of other national JEMs. For example it was used in the NOCCA study to construct NOCCA-JEMs, covering Sweden, Norway, Denmark and Iceland (see Section 3.1.1) (Kauppinen *et al.*, 2009). Some JEMs which are partially based on FINJEM (for example NOCCA-JEMs, INTEROCC-JEM) were constructed mainly for exposure assessment purposes in large epidemiological studies, but national figures on the numbers of exposed workers and their exposure levels have not been reported (Kauppinen *et al.*, 2009; van Tongeren *et al.*, 2013).

Other JEMs which have used FINJEM as the basis for the assessment of chemical exposures include the INTEROCC-JEM, constructed for the exposure assessment on a large international study on brain cancer (van Tongeren *et al.*, 2013), and the Spanish MatEmESp exposure information system (Garcia *et al.*, 2013). FINJEM estimates were adapted to Spanish working conditions by local experts and Spanish surveys were used to obtain exposure estimates for ergonomic and psychosocial risk factors. The utility of the database can be seen through some examples: the data from it have shown that the most prevalent occupational hazards are repetitive movements and a lack of support from co-workers; that 10% of the Spanish working population have to work night shifts; and that bricklayers and concrete workers are the occupations with the highest risk of exposure to quartz dust.

Matgéné (France)

France has a programme called Matgéné which has developed JEMs for chemical agents including carcinogens such as silica, asbestos, benzene, formaldehyde, PAHs and some chlorinated hydrocarbons (Févotte *et al.*, 2006, 2011). Each JEM is specific to one agent, assessing exposure for a set of homogeneous combinations (occupation × activity × period) according to two occupational classifications (ISCO[2], 1968; and PCS[3], 1994) and one economic activities classification (NAF[4], 2000). The JEMs estimate prevalence and level of exposure'. The level is estimated by the duration and intensity of exposure-linked tasks or by a description of the tasks when exposure measurement data are lacking for the agent in question. The JEMs were applied to a representative sample of the French population in 2007, and prevalence for each exposure was estimated in various population groups[5].

[2] The International standard classification of occupations, abbreviated as ISCO, is an international classification under the responsibility of the International Labour Organization (ILO) for organising jobs into a clearly defined set of groups according to the tasks and duties undertaken in the job. ISCO is intended both for use in compiling statistics and for client-oriented uses such as the recruitment of workers through employment offices, the management of migration of workers between countries and the development of vocational training programmes and guidance.

[3] Position classification standard

[4] The French classification of activities (NAF Rev. 2, 2008) is the national statistical classification of activities which has superseded since January 2008 NAF rev. 1, the latter being in use since January 2003.

[5] see at: http://www.invs.sante.fr/Dossiers-thematiques/Travail-et-sante/Matrices-emplois-expositions

The Matgéné programme has reported prevalence of exposure and those where there is a substantial exposure to carcinogens Substantial exposures to carcinogens reported by Matgéné are shown in Table 14) (Févotte *et al.*, 2006 and 2011). The MATPHYTO database covers exposures to pesticides among agricultural workers linked to certain crops.

Specific JEMs have been developed based on Matgéné for exposures to leather dust (INVS, 2006), fuels and petroleum solvents (INVS, 2007a, 2007b), mineral wools (INVS 2008, 2012a), selected chlorinated solvents (tri- and perchloroethylene, methylene chloride, carbon tetrachloride, chloroform) (INVS, 2009a, 2009b), flour dust, crystalline silica (INVS, 2010a, 2010b), and refractory ceramic fibres (INVS 2012a, 2012b).

Further JEMs are under development for formaldehyde and other organic solvents.

Table 14: Prevalence estimates (P, % of the employed aged 25–74) of exposure and of substantial exposure* in France in 2007 for selected agents assessed in the Matgéné programme

Agent	Unit	OEL	SET	P, men	$P_{substantial}$ men	P, women	$P_{substantial}$ women
Leather dust	mg/m^3	10	1	0.11	0.11	0.07	0.07
Silica	mg/m^3	0.1	0.1	5.60	1.49	0.33	0
Asbestos	f/ml	0.1	0.1	1.14	0.49	0.11	0.01
Benzene	mg/m^3	3.25	3.25	1.26	0	0.06	0
Trichloroethylene	mg/m^3	405	135	0.30	0	0.02	0
Perchloroethylene	mg/m^3	335	167	0.08	0	0.02	0
Chloroform	mg/m^3	12	–	0.03	0	0.05	0

*Substantial prevalence is calculated by excluding low-level exposure (below the substantial exposure threshold) from prevalence.

SET, substantial exposure threshold

Source: Févotte *et al.*, 2011

SUMER survey (France)

The SUMER survey (the Medical Monitoring Survey of Professional Risks) is another French dataset including information on carcinogen exposure. It has been carried out in 1994, 2003 and 2010. Reports on those surveys are available from the website of the statistical department of the French Ministry for Labour, DARES (DARES Website, SUMER 1994, 2003, 2010). One of the survey's main functions is to identify occupational risks and to develop an agenda for the prevention of the most common threats. The SUMER survey consists of interviews with employees conducted by the company medical officer occupational health physicians) who belong to intercompany services during employees' regular compulsory medical examinations. The report on the 2003 survey included 28 agents which IARC classified as being at least possibly carcinogenic, for example diesel exhaust, wood dust, silica, trichloroethylene, formaldehyde, chromium and asbestos. Data are available subdivided by the characteristics of the interviewed subjects (sex, age, industry, socioeconomic status) and several scores describing the level of exposure are used.

The results on occupational exposure to carcinogens in the French **SUMER** survey for the years 2003 and 2010 have been reported (see Table 15 (DARES, 2005 and 2013). Sumer 2003 did not cover all the workforce but private sector employees which represent altogether 70% of total employees (excluding employees of particular (private) employers) and public hospitals. In 2010, a number of public service organisations were also included.

In 2003, the prevalence of exposure to any agent in the table was 13.5% of the workforce considered with men being more frequently exposed (20.4%) than women (4.3%). Among young workers (< 25 years), the prevalence of exposure was above average (17.1% in 2003 and 16% in 2010), twice that among older workers (> 50 years, 8%). More young workers also have multiple exposures to carcinogens. The weekly duration of exposure was less than 2 hours in 45% of cases in 2003 and 47% in 2010, but at least 20 hours in 18% of cases in 2003 and 15% in 2010. The intensity of exposure was assessed as very low in 36% of cases in 2003 and 38% in 2010 and as very high in 2% of cases in 2003 and 2010. No collective protection (such as local exhaust ventilation) was used in 39% of cases in 2003 and 35% in 2010, and no personal protection was used in 55% of cases in 2003 and 46% in 2010. On average, personal protection measures have increased. Dermal protection was used in 37% of cases in 2003 and 42% in 2010, and respiratory protection was used in 19% of cases in 2003 and 31% in 2010. Eye protection was used in slightly more than a quarter of the cases in 2010 (26%, against 19% in 2003). However, it is not known whether these protection measures are appropriate and targeted to the agents in question.

In 2010, on average, collective protection measures were applied in 21% of cases, and general ventilation in 19%. However, there are considerable differences between SMEs, nearly half of which (44%) did not apply collective measures, and large enterprises (> 500 workers), of which a quarter (25%) did not apply collective measures. In addition, the proportion of workplaces where measures at the source such as local exhaust ventilation are applied has decreased. General ventilation does not seem appropriate to protect workers from exposure to carcinogens, as the substance is spread over the workspace. The preferred option according to the hierarchy of control measures defined in the Carcinogens Directive, the use of a closed system, is applied in only 1% of the cases, based on 2010 figures (DARES 2013).

Among young workers, apprentices and workers on training schemes were particularly likely to be exposed. Metal manufacturing stands out, with 70% of apprentices exposed, against 35% of all workers. Higher exposures were also found for temporary workers and maintenance workers. Exposures to three or more listed carcinogens in the week before the survey were recorded for 1% of the workers, and they affect the same categories of workers, with high proportions in maintenance (8% exposed), and construction (5%), among young workers below 30 years (2%) and in small enterprises (2% of the workers exposed).

Young worker performing car maintenance

The 2010 SUMER analysis distinguished three groups of substances:

- Group 1 includes asbestos, tricholoroethylene, sintered metals, cytostatic drugs, benzene; exposures were generally short and limited. These substances are highly toxic and therefore, for deliberate uses, there are highly developed technologies, combining collective protection and personal protection measures, to avoid exposure. The number of exposures is estimated at 271,000.
- Group 2, to which 38% of the workers are significantly exposed, are substances for which control measures are difficult to implement, as they are process-generated, for example combustion products such as diesel exhaust, welding fumes, soot and tar, bitumen and crystalline silica. A notable proportion of these exposures are of longer duration, more than 10 hours per week, and high or very high. These exposures are the most common and represent the major part of exposures (1.7 million).
- Group 3 are exposures between the two above-mentioned groups and also include process-generated substances (metals, cutting fluids, nitrosamines, vulcanisation fumes, resins). They account for 1.3 million exposures.

Table 15: Estimates of occupational exposure to carcinogens in France in 2003 and 2010 according to the SUMER surveys

Agent	Number of exposed (in thousands)		% of employed	
	2003	2010	2003	2010
Diesel exhaust	728	798	4.2	3.7
Mineral oils	669	538	3.8	2.5
Wood dust	380	370	2.2	1.7
Crystalline silica	269	295	1.5	1.4
Trichloroethylene	154	64	0.9	0.3
Formaldehyde	154	139	0.9	0.7
Lead and its compounds	NR	115	NR	0.5
Oil-based tars, bitumen	117	111	0.7	0.5
Chromium and its compounds	108	96	0.6	0.4
Asbestos	107	81	0.6	0.4
Halogenated or nitrated hydrocarbons	104	106	0.6	0.5
Ceramic fibres	104	79	0.6	0.4
Nickel and its compounds	98	93	0.6	0.4

Agent	Number of exposed (in thousands)		% of employed	
	2003	2010	2003	2010
Metallurgical emissions	93	72	0.5	0.3
Aromatic amines	71	63	0.4	0.3
Cytostatic drugs	70	49	0.4	0.2
Cobalt and its compounds	48	66	0.3	0.3
Benzene (except from petrol)	48	37	0.3	0.2
Perchloroethylene	47	30	0.3	0.1
Phenol-formaldehyde resins	39	25	0.1	0.1
Vulcanisation fumes	38	16	0.2	0.1
Sintered metal carbides	37	39	0.2	0.1
Acrylamide	28	30	0.2	0.1
Cadmium and its compounds	28	40	0.2	0.2
Epichlorohydrine	20	NR	0.1	NR
Arsenic and its compounds	14	8	0.1	< 0.1
PBBs or PCBs	10	NR	0.1	NR
Ethylene oxide	9	NR	0.1	NR
Nitrosamines	5.5	NR	0.0	NR

NR, not reported

Source: DARES, 2005 and 2013

The SUMER survey also provides figures by gender (

Table 16). Women seem to be more exposed in the public than in the private sector, which may be explained by the fact that a high proportion of women work, for example, in the health-care sector.

Table 16: Exposure to chemicals and chemical carcinogens by gender in the public and private sector according to SUMER 2010

	All workers			Private sector		Public sector	
	Men	Women	Average	Men	Women	Men	Women
Exposed to at least one chemical	37.5	27.9	33.2	38.8	24.8	29.1	38.9
Exposed to at least three chemicals	17.8	9.5	14.0	18.6	7.9	12.5	14.9
Exposed to at least one solvent	14.0	12.0	13.1	14.5	9.1	10.8	21.9
Exposed to at least one carcinogen	16.1	2.8	10.1	17.0	2.7	11.0	3.0
Exposed to at least one chemical for more than 10 hours per week	12.4	5.2	9.2	13.5	4.5	5.7	7.5
Exposed considerably in duration or intensity	7.4	3.0	5.4	8.1	2.8	2.7	3.8

Source: SUMER 2010 - DARES 2013

The SUMER survey also provides some figures on exposures to other risk factors for cancer (Table 17).

Table 17: Exposures to other cancer risk factors according to SUMER 2010

Agent	Number of exposed workers	Proportion of exposed workers (%)	Proportion of scores over 1*
Welding fumes (metals)	598,000	2.8	44
Ionising radiation	259,000	1.2	n. a.
Night shift work, including occasionally	3,141,000, of which 759,000 are women	14.5	n. a.

* Very weak exposures of less than 10 hours or weak exposures (< 50% OEL) of less than 2 hours

n.a. not applicable

Source: SUMER 2010 – DARES 2013

There are also other surveys, databases and reports that include some information about exposure to carcinogens (see, for example, Table 7).

2.2.5. *Non-chemical carcinogens*

Some of the sources described in Sections 2.2.1–2.2.4 include exposure information on factors other than chemical agents. They are listed in Table 18, which includes also some new sources, such as international surveys.

Table 18: Sources of exposure information on non-chemical factors associated with cancer

Non-chemical factor	Sources of information	Remarks
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

EWCS, European Working Conditions Surveys

Source: Overview by the authors

- **Radiation and electromagnetic fields**

According to CAREX, **solar radiation (UVR)** is the most common carcinogenic physical exposure in the EU. Close to 9 million regular outdoor workers were exposed to sunlight in 15 Member States in 1990–3. Exposure was particularly common in agriculture (2.5 million exposed) and construction (2.1 million exposed) (CAREX website). In Canada, 1.5 million workers (close to 10% of the workforce) are exposed to solar radiation. The major industries where exposure occurs are construction, farms and services for buildings and dwellings. The most commonly exposed worker's occupations with the highest numbers of workers exposed are farmers, construction workers, and landscaping and grounds maintenance labourers. This does not include exposure to artificial UVR (such as in welding); about 140,000 workers are exposed to artificial UVR according to CAREX Canada.

The CAREX estimate of exposure to **ionising radiation** for 15 Member States of the EU in 1990–3 is that 140,000 were exposed. According to the CAREX website, exposure occurs frequently in energy production (nuclear power plants and so on; 47,000 exposed), air transport (cosmic radiation, high-altitude flights; 41,000 exposed) and medical services (X-rays, use of radionuclides; 26,000 exposed). The CAREX Canada estimate for ionising radiation is that 38,000 are exposed. CAREX has a separate estimate for **radon**, which is a radioactive gas. Workers who work underground or on the ground floors of buildings in regions where the natural radon level in the bedrock is high may be considered to be occupationally exposed during their work. The CAREX estimate for radon exposure at work is 2.7 million, which is much higher than the estimate for the other types of ionising radiation. The majority of exposure originates from regular indoor work in offices, shops and other workplaces close to the ground or underground.

Neither CAREX nor CAREX Canada estimates workers exposed to **electromagnetic fields**, which have been associated with a cancer risk. There are several electromagnetic field JEMs for electric utility workers and some that cover all occupations. A population-based JEM for electromagnetic field exposure was developed in the United States on the basis of a Swedish JEM and measurements carried out in the United States and some other countries (Bowman, Touchstone & Yost, 2007). This JEM was, however, intended to be used in epidemiological studies, and it provides measurement-based or inferred estimates of levels of exposure to electromagnetic fields by occupation. No figures on the numbers of exposed workers or prevalence of exposure among the employed have been reported based on this JEM. Another JEM, on extremely low-frequency magnetic fields, which is partially based on the JEM by Bowman, has recently been developed in the Netherlands (Koeman *et al.*, 2013). The FINJEM estimates of electromagnetic field exposure add up to 470,000 exposed workers out of an employed population of 2.5 million (prevalence 19%), but the prevalence depends strongly on whether or not it includes the minimum exposure (FINJEM definition: occupational exposure to low-frequency(< 1 kHz) magnetic fields over 0.5 µT. FINJEM assessment threshold: at least 5% of the occupation exposed to mean daily magnetic field exceeding 0.5 µT. Non-occupational daily exposure originating from leasure-time activities does not usually exceed 0.2 µT). Radiofrequency electromagnetic fields have been classified 2B by the IARC in 2013. That includes radiofrequency electromagnetic fields from wireless phones.

Biological risks

No estimates of exposure to **hepatitis viruses** appear to have been published. For example, the extent and level of exposure to viruses depends on the prevalence of patients carrying the virus and the frequency of exposure to blood. Most of the potentially exposed subjects would be expected to work in hospitals or in other health-care units. Some of the exposed workers may be registered as having an occupational disease in national registers. According to statistics from Eurostat, 40 cases of hepatitis A, 10 cases of hepatitis B and 146 cases of hepatitis C were recognised as occupational diseases in 12 Member States of the EU in 2001 (Karjalainen and Niederlander, 2004). However, the number of workers exposed is likely to be much higher. Some of the workers potentially exposed have been vaccinated against some types of hepatitis virus, and this may protect them should they be exposed.

Organisational risks

Every fifth year (in 1991, 1996, 2000, 2005 and 2010) Eurofound carries out a survey of working conditions (EWCS (European Working Conditions Survey)). The numbers of individuals interviewed and countries covered has risen from 12,500 workers and 12 countries to 44,000 workers and 34 countries over the years. The scope of the survey questionnaire has broadened substantially since its first edition. Gender related topics have been an important concern in recent reports on the survey results. The themes covered today include employment status, working time duration and organisation, work organisation, learning and training, physical and psychosocial risk factors, health and safety, work–life balance, worker participation, and earnings and financial security, as well as work and health. The survey also includes questions about **shift work and night work**. Close to 20% of the workforce in the 27 Member States of the EU had to work in shifts or at night in the period 2000–10 (see Table 19). The difference between genders in shift work is small, but men tend to work at night more frequently. Elderly people work less often in shifts and during the night. Shift work and night work are, on average, approximately equally common in the manufacturing and service industries. Employees in low-skilled manual occupations work in shifts and during the night more often than other occupational groups. Shift work is more common in the Czech Republic (25%) and Slovakia (23%) and less common in Denmark (7%) and the Netherlands (7%) than on average in the EU-27. Working at night is more common in Ireland (26%) and the Czech Republic (26%) and less common in Cyprus (10%), Italy (13%) and Spain (13%) than on average in the EU-27.

Table 19: The proportion (%) of the employed that worked in shifts or during the night at least once a month, including at least two hours between 22.00. and 05.00 in 27 Member States of the EU in 2000–10

	Shift work			Night work		
	2000	2005	2010	2000	2005	2010
All	20	17	17	19	19	18
Men	20	17	17	24	24	22
Women	19	17	17	12	13	14
Under 30 years	21	20	21	19	20	17
30–49 years	21	18	17	20	21	19
> 50 years	15	13	14	16	16	16
Industry	21	17	16	19	18	16
Services	19	17	18	19	20	19
High-skilled clerical	11	11	9	18	19	19
Low-skilled clerical	20	18	20	16	16	16
High-skilled manual	16	14	12	17	17	13
Low-skilled manual	32	25	26	28	28	25

Source: Eurofound, EWCS 2000, 2005 and 2010).

According to CAREX Canada, 13% of the employed (1.9 million) work in rotating shifts or regular night shifts. The industry groups with the greatest numbers of people working regular night or rotating shifts are manufacturing (n = 419,000; 21% of the employed), trade (n = 382,000; 16%), health care and social assistance (n = 284,000; 18) and accommodation and food services (n = 247,000; 23%). Health care and social assistance, trade, and accommodation and food services predominantly employ women, while manufacturing, business, building and other support services, and public administration predominantly employ men in shift or night work (CAREX Canada, 2013).

Rushton and colleagues (Hutchings *et al.* 2012) outlined how prevention could help reduce cases of breast cancer linked to night shift work. This would involve taking specific measures such as limiting years working shifts.

Reducing the burden of breast cancer linked to shift work (United Kingdom)

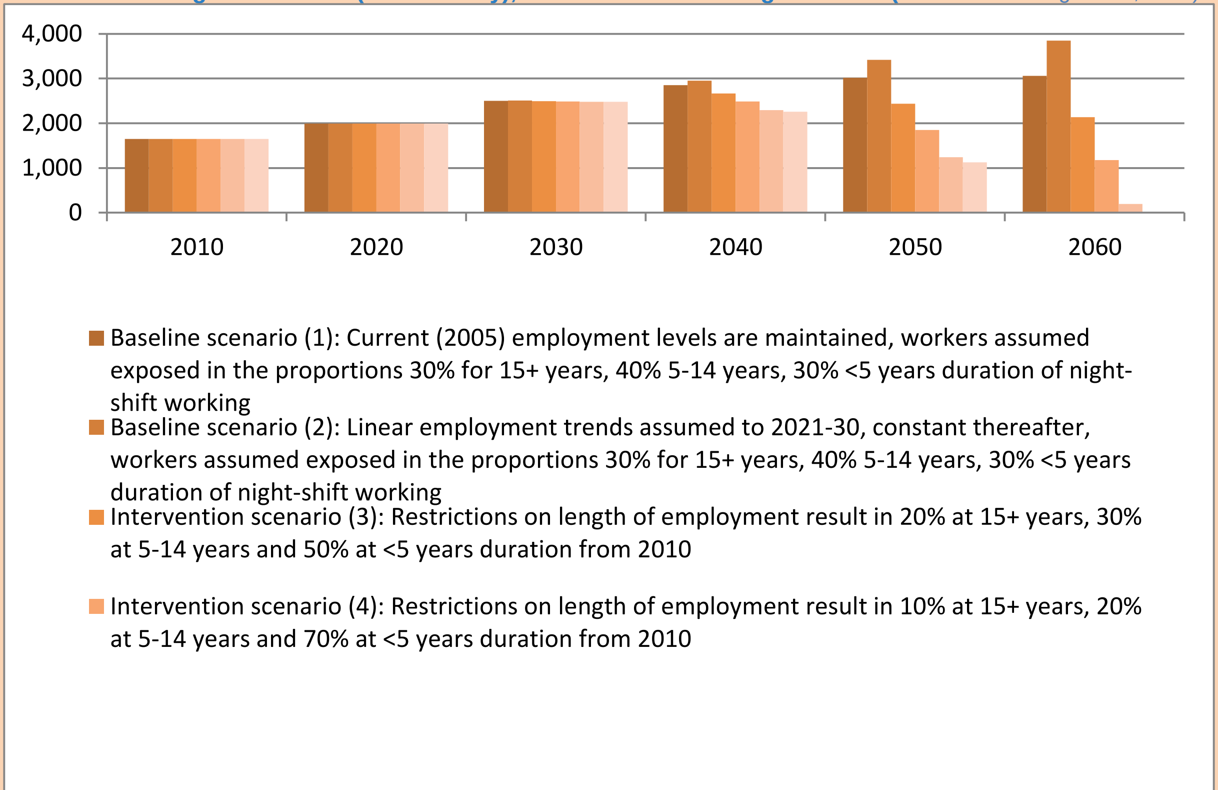
Estimates of the future burden of occupational cancer in the United Kingdom under a series of scenarios of change were calculated in a study by Hutchings *et al.* (2012). With regard to shift work, six different scenarios were used, assuming that the exposure time for shift work was restricted:

1. Base level scenario where current (2005) employment levels are maintained, proportion exposed by years of night shift working, 30% < 5, 40% 5–14, 30% ≥ 15;
2. Linear employment trends assumed to 2021–30, constant thereafter, proportion exposed by years of night shift working: 30% < 5, 40% 5–14, 30% ≥ 15;
3. Proportion exposed by years of night shift working 50% < 5, 30% 5–14, 10% ≥ 15 from 2010;

4. Proportion exposed by years of night shift working 70% < 5, 20% 5–14, 10% ≥ 15 from 2010;
5. Proportion exposed by years night shift working 90% < 5, 10% 5–14, 0% ≥ 15 years from 2010;
6. 100% of workers restricted to < 5 years' duration from 2010.

The underlying assumption is that a considerable number of cases could be avoided by restricting long-term exposure to night shift work that disrupts circadian rhythm; the most effective measure would be the restriction of night shift work to less than 5 years' duration (Figure 3).

Figure 3: Results for baseline and intervention scenarios 1–6 (described in text) for breast cancer attributable to night shift work (women only), in terms of cancer registrations (Source Hutchings *et al.*, 2012).



2.2.6. *Vulnerable groups*

Table 20 lists sources which include information about occupational exposure to carcinogens in worker groups that may be at a higher than average risk of contracting occupational cancer because of their personal characteristics or who have a higher than average exposure to carcinogens. Pregnant women may be considered a vulnerable group because exposure may be harmful to the unborn child. Since there is no information about the numbers of pregnant women exposed, we have listed sources of data that provide information broken down by gender. The numbers of exposed women may be used to estimate those of exposed pregnant women. 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. Table 20 also lists sources of data that provide information subdivided by age of exposed workers. The data on workers with high exposure mentioned in the table are gathered from sources which provide data according to the level of exposure, either in semi-quantitative terms (such as 'high exposure') or in quantitative terms (such as 'level exceeding 50% of the OEL'). It has been argued that some groups can be considered as "inherently" vulnerable, the "particularly sensitive risk groups" (ageing workers, young workers, female workers,…), whilst for workers with high levels of exposure, the vulnerability can be attributed to the job itself (and possibly to the fact that in that sector, the high level of exposure is due to the fact that OSH regulations aren't respected). However, there is an overlap between these groups, and the different conditions may interact. Consequently, the differences in metabolism, preexisting health problems, including those caused by work such as respiratory disorders, 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.

Table 20: Sources of exposure information on carcinogen exposure of some vulnerable groups

Vulnerable group	Sources of information	Remarks
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 those identified in section 2.2.2.	The definition of 'high' varies by source

Source: Overview by the authors

According to the French SUMER survey, the prevalence of exposure among **young workers** (under 25 years) was higher (16%) than the average value among the employed (10%) (DARES, 2013). The 2010 SUMER survey established that 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. Exposures are also higher in low-qualified jobs (DARES, 2013). Before the prohibition of smoking in restaurants in Finland in 2005, many young workers (under 25 years) were exposed to ETS, and most of them were women (Saalo *et al.*, 2007). In an Australian interview study (described in section 3.1.5.), exposure prevalence was highest among farmers, drivers, miners and transport workers, as well as in men and in those individuals residing in regional areas (Carey *et al.*, 2014). Extrapolation to the Australian working population would mean that more than 40% (3.6 million) could be exposed to at least one carcinogen in the workplace.

Women are usually reported to be less frequently exposed to carcinogens than men in industrialised workplaces. The proportion of men among workers affected by the most common carcinogenic exposures was 74–93% according to CAREX Canada (see Table 11). Exposed workers notified to the Finnish ASA Register are predominantly men (80%) (Saalo *et al.*, 2012). However, common exposures to diesel exhaust, ETS and solar radiation are not reported to these registers and the substances covered by these registers relate mainly to industrial jobs with a high proportion of male workers. According to the French Matgéné estimations, men were exposed to seven agents more frequently than men, with the reverse true only of one (chloroform) (see Table 14). In the French SUMER survey, the prevalence of exposure to agents associated with cancer was 16% for men and only 3% for women (DARES, 2013). According to Costa Rican TICAREX estimates, men were exposed to 26 carcinogens more frequently than women, and women were exposed more than men to only one (ethylene oxide, probably in hospital environments) (Partanen *et al.*, 2003). While this indicates that women are less frequently exposed to these carcinogens than men, some experts have challenged these findings, arguing that there are groups whose occupational exposure to cancer risks and carcinogenic factors and conditions are underrepresented in the exposure data, because the exposures considered are usually biased towards industrial occupations and towards exposures where measurements are available (for example, there is less knowledge about exposure in service sector jobs) (EU-OSHA 2013, 2014). In selected workplaces, women can be highly exposed (for example to formaldehyde in the textile industry, leather dust in shoemaking, ethylene oxide and cytostatic drugs in health care, diesel exhaust in transport).

Worker groups exposed to high levels of carcinogens may be identified by examining CAREX Canada, FINJEM, Matgéné estimations, SUMER survey and WOODEX (for indicators of high exposure, see sections 2.2.2. to 2.2.6.). In addition, exposure measurement registers, scientific articles and other reports may include information on work tasks and occupations involving high exposures to carcinogens. However, detailed data on levels of exposure by occupation or work task are often so comprehensive that they are not published in full. Since maintenance work tasks are not continuous, there are not many measurements available for that field. Furthermore, frequent changes in a job, for example for subcontracted workers or workers who work at clients´ premises, or on construction sites, make it difficult to assess exposure to carcinogens. As mentioned in studies on the Finnish ASA system (Kauppinen *et al.* 2007), exposures that were short or occasional tend to go unreported. Finding the ‘worst’ carcinogen exposures is also a challenging task. Measurement data may be biased, estimates may be erroneous and even the carcinogenic potential of the different agents may vary widely.

Another ongoing study aiming at the identification and prevention of the most harmful chemical exposures is introduced in Section 3.1.4.

3. New approaches to the assessment and prevention of occupational cancer

From the point of view of preventing occupational cancers, it is important to gather knowledge on the levels of exposure in different sectors, occupations, jobs and tasks. This chapter presents further developments of the systems described in the previous chapter to address some of the information gaps identified (development of exposure over time, identification of highly exposed workers, exposure profiles) and new approaches aiming to identify cancer cases linked to multiple exposures or work organisational factors. It also presents approaches in which data and research results are directly linked to prevention measures and guidance for workplaces.

3.1. Further developments and uses of exposure measurements and estimates

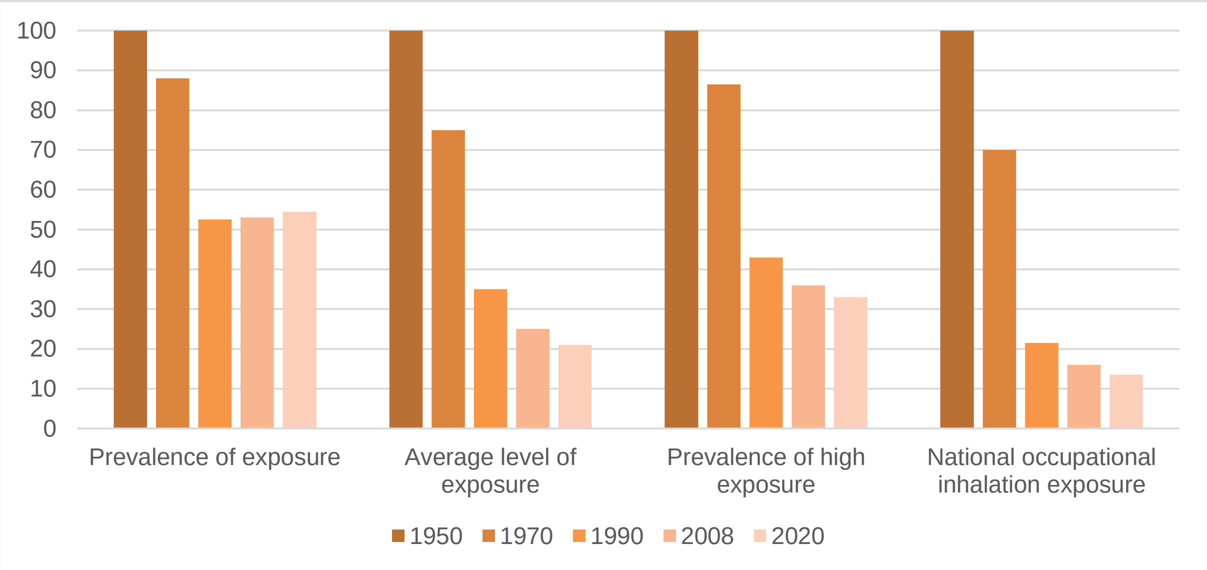
3.1.1. Information on exposure trends and prediction of future exposures: the FINJEM-based trend study

The effective prevention of work-related diseases caused by chemical exposure requires knowledge of exposure trends. For example, 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 (Rushton et al., 2012; Nurminen and Karjalainen, 2001). From the point of view of prevention, it would be beneficial to estimate the effects of present exposure on future risk, evaluating the potential short- and long-term health effects and how often they may occur in workers. This would require information on the numbers of exposed workers and their levels of exposure over time and on the health effects of the exposures. Unfortunately, quantitative estimates of this type of data are not usually available. Temporal trends are important also in occupational epidemiology. The estimation of the exposure of the subjects under study is more valid if changes in exposure over time can be taken into account. Analyses of exposure trends also indirectly provide information on the success or failure of preventive measures which have been taken. From this perspective, it is important that the risk groups experiencing high exposure can be followed over time. Further preventive measures can then focus on those risk groups in which development has not been favourable.

Long-term trends of occupational exposure to major chemical agents were estimated quantitatively in Finland (Kauppinen et al., 2013). The trend analysis of chemical exposure is intended to serve several purposes, such as hazard surveillance, quantitative risk assessment, exposure assessment in occupational epidemiology, setting of priorities for preventive measures and prediction of future risks of illness.

Trends were estimated using FINJEM, which includes occupation-specific estimates of the prevalence (P, % of employed) and average level (L, agent-specific units) of inhalation exposure to chemical agents at different time periods. FINJEM data were used to calculate national estimates of the numbers of exposed workers (Nexp), and the prevalence of as well as the level of exposure to 41 chemical agents in 1950, 1970, 1990 and 2008. The proportion of workers exposed to levels exceeding 50% of the Finnish OEL (Phigh) and national occupational inhalation exposure (NOIE = Nexp*L) were also assessed. NOIE is a measure of total inhalation exposure in a country, which takes into account both the number of exposed workers and their average exposure level. This 'national dose' predicts the agent-specific burden of work-related diseases in Finland. Dermal exposure to chemical agents was assessed indirectly from the statistics on occupational skin diseases in 1975–2009. According to the results, inhalation exposure to most chemical agents had decreased. Using 1990 as the reference (100), the median values of P for 1950, 1970, 1990, 2008 and 2020 were 91, 149, 100, 58 and 41, respectively. The corresponding values were 218, 224, 100, 30 and 14 for P_{high}, 151, 121, 100, 78 and 66 for L, and 119, 176, 100, 38 and 20 for NOIE. The trends varied considerably according to the agent. Exposure to some carcinogens, such as asbestos, benzene and benzo(a)pyrene had substantially decreased. The trend for exposure to crystalline silica was also decreasing, indicating that in the future we can expect reductions in the numbers of patients with silicosis, lung cancer and other diseases caused by inhalation exposure (see Figure 4). An example of an exposure which has not decreased greatly over time is diesel exhaust. In contrast, the annual incidence of occupational skin diseases caused by chemical factors has declined from 6.9 per 10,000 employed in 1975–9 to 4.6 per 10,000 employed in 2000–9, pointing to a decrease in dermal exposure.

Figure 4: Occupational inhalation exposure to crystalline silica (quartz dust) in Finland in 1950, 1970, 1990 and 2008 and predicted for 2020, as measured by four different metrics of exposure. Proportional values as compared with 1950 (baseline = 100).



Source: FINJEM database (FIOH, 2013b)

Compared to the FINJEM trend study, which is partly based on estimates and data from occupational diseases statistics, trend data has previously been reported mainly by the level of exposure based on exposure measurements in other studies. A large review of trends in exposure measurements (Creely *et al.*, 2007) reports a median annual decrease in exposure by 8%, which is much greater than the 1% reported by the FINJEM trend analysis. A possible reason for this difference is that the measured concentrations relate mainly to substances for which exposures are high, and for which the FINJEM analysis also provides higher rates of annual decrease in exposure (for example, median 7% in 1990–2008). It is worth noting that different exposure metrics show different temporal patterns. For example, the medians of prevalence and NOIE increased in 1950–70 in spite of the decreasing average level and prevalence of high exposures. These exposure metrics have different fields of use: NOIE is useful in burden assessments, the prevalence of high exposures is beneficial in priority setting for prevention, and the prevalence and level of exposure in various occupations are mainly used in occupational epidemiology.

Exposure trends identified in Finland

Inhalation exposure to most chemical agents has decreased in Finland since 1970. High exposures and the average level of exposure had already started to decline in the 1950s. The declining incidence of occupational skin diseases suggests that dermal exposure has also diminished. However, high exposures still exist and are responsible for a substantial amount of occupational diseases and symptoms. Chemical exposures and the related disease burden are expected to continue to decrease in the future. These results and trends cannot be directly generalised to other countries, particularly where the pace of technological development and the occupational structure of the labour force differs significantly from those in Finland.

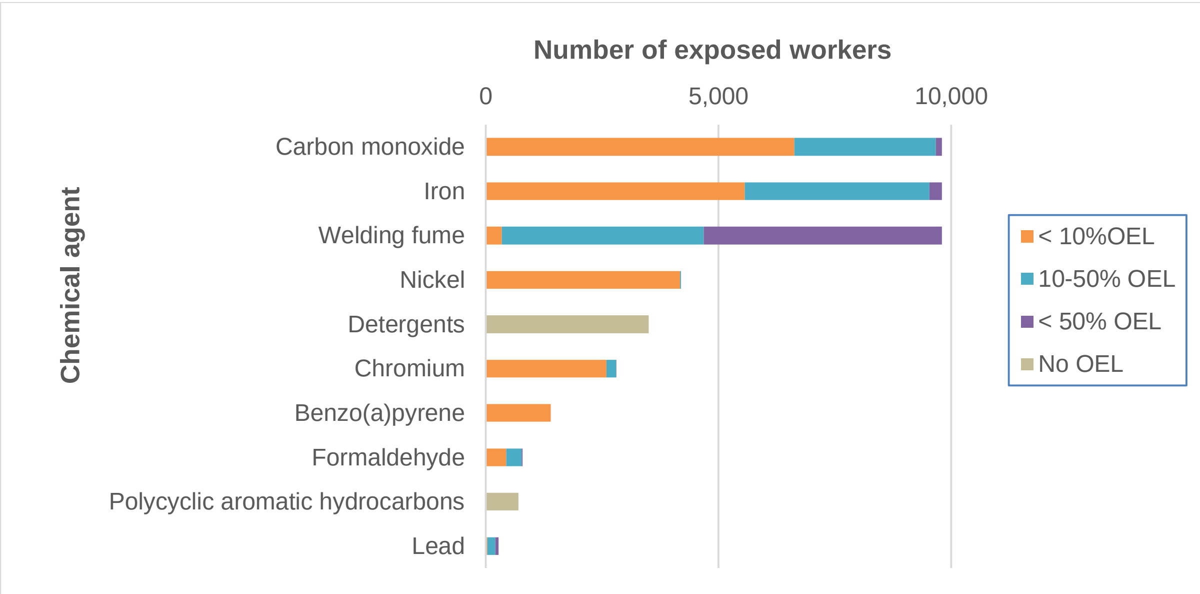
The FINJEM-based trend analysis included the prediction of exposures by 2020, using the same metrics of exposure as in 1950–2008. Changes in the economic structure and distribution of occupations could be taken into account, but no reliable models were available with which to estimate future agent-specific changes within occupations.

The trend analysis of past exposures indicates that regulations, technology and labour safety measures may have clear influences on both the prevalence and the level of exposure, and furthermore that the influence is agent-specific. The predictions for 2020 were, therefore, based on changes in occupational structure and extrapolation of the trends in exposure observed for the previous period, 1990–2008, which were assessed agent by agent and occupation by occupation by experts, supported by measurement data whenever available. The resulting estimates for 2020 should be considered crude figures the reliability of which is not high.

3.1.2. Occupational exposure profiles based on job–exposure matrices

FINJEM also provides profile data subdivided by occupation and by agent. An example of occupational exposure profiles of one occupation and of one agent are shown in Figure 5 and Figure 6.

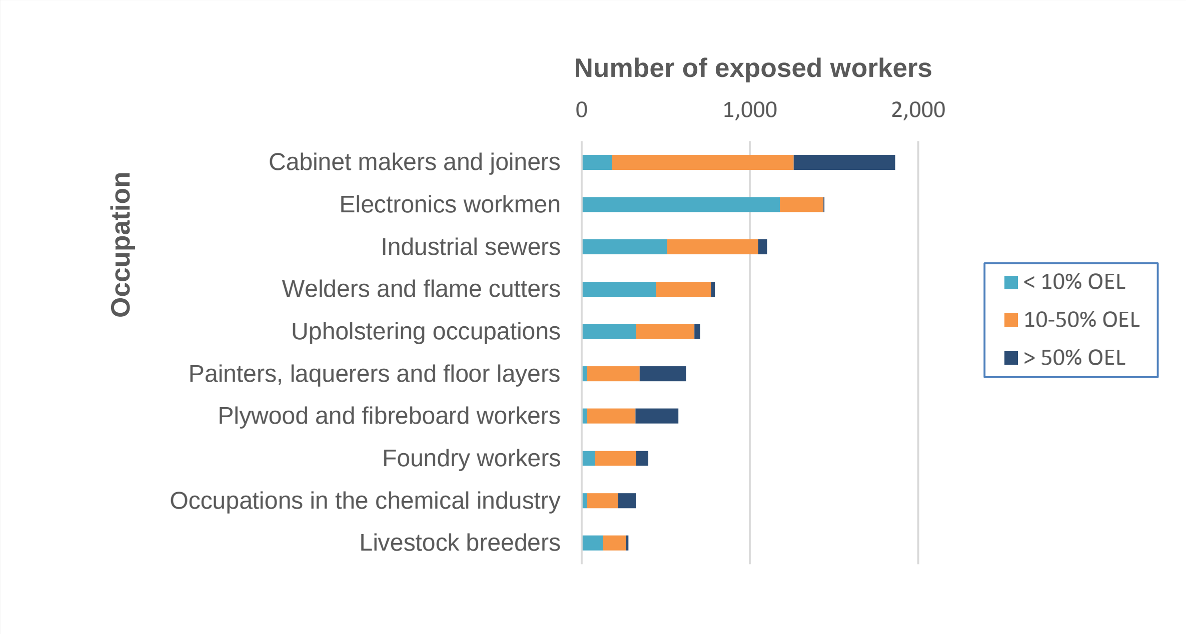
Figure 5: Occupational exposure profile for welders and flame cutters in Finland in 2007–9; numbers of workers exposed to chemical agent and average level of exposure compared with the Finnish OEL in 2009*



* The chemical agents with the ten highest numbers of exposed workers are shown in the figure.

Source: FINJEM database (FIOH, 2013b)

Figure 6: Occupational exposure profile for formaldehyde in Finland in 2007–9; numbers of workers exposed to formaldehyde subdivided by occupation and the average level of exposure compared with the Finnish OEL in 2009 (0.3 ppm)*



* The occupations with the ten highest numbers of exposed workers are shown in the figure.

Source: FINJEM database (FIOH, 2013b).

3.1.3. Distribution by exposure level: WOODEX – International information system on occupational exposure to wood dust

The international information system on occupational exposure to wood dust (WOODEX) was constructed based on the CAREX approach and incorporating the level of exposure using similar principles to CAREX Finland. The aim of the WOODEX project was to estimate occupational exposure to inhalable wood dust by country, industry, level of exposure and type of wood dust in 25 Member States of the European Union (EU-25) for the purposes of hazard control, exposure surveillance and assessment of health risks. Because estimates were generated only for wood dust, it was possible to collect comprehensive data from industrial hygiene measurements and to carry out a questionnaire survey of wood-related workplaces, thereby increasing the validity of the final estimates. National labour force statistics, a country questionnaire (in 15 Member States, EU-15), a company survey (in Finland, France, Germany and Spain), exposure measurements (from Denmark, Finland, France, Germany, the Netherlands and the United Kingdom) and expert judgments were used to generate preliminary estimates of exposure to different types of wood dust. The estimates were generated according to industrial class (six wood industry sectors, four other sectors) and level of exposure (five classes). These estimates were reviewed and finalised by national experts from 15 'old' Member States. Crude estimates were generated for 10 'new' Member States (EU-10) (Kauppinen *et al.*, 2006).

The WOODEX project provided results only on one agent, wood dust. The type of wood (oak, beech, and so on) was addressed in company and country questionnaires. However, it was unfeasible to estimate the numbers of exposed workers and their levels of exposure to specific species of wood because of the simultaneous use of many species of wood and different kinds of wooden boards with variable composition. According to the results, about 3.6 million workers (2.0% of the employed EU-25 population) were occupationally exposed to inhalable wood dust in 2000–3. The numbers of exposed workers varied by country, ranging from fewer than 3,000 in Luxembourg and Malta to more than 700,000 in Germany (see Table 21).

Table 21: Numbers of workers exposed to inhalable wood dust, and distribution of exposed workers (%) by country and level of exposure in 25 Member States of the European Union (EU-25) in 2000–3

Country	Exposed	Exposed (% of employed)	< 0.5 mg/m³	0.5–1 mg/m³	1–2 mg/m³	2–5 mg/m³	> 5 mg/m³
Austria	84,000	2.8	19,000	15,000	18,000	20,000	12,000
Belgium	51,000	1.2	7,000	8,000	12,000	14,000	9,000
Cyprus	8,000	2.5	1,600	1,400	1, 800	2,000	1,200
Czech Republic	148,000	3.1	40	25,000	30,000	33,000	20,000
Denmark	72,000	3.3	20,000	16,000	16,000	14,000	7,000
Estonia	27,000	4.6	8,000	5,000	5,000	5,000	3,000
Finland	65,000	2.7	24,000	12,000	12,000	11,000	6,000
France	308,000	1.3	68,000	52,000	65,000	75,000	47,000
Germany	704,000	1.9	143,000	119,000	153,000	178,000	110,000
Greece	70,000	1.7	13,000	10,000	15,000	19,000	13,000
Hungary	62,000	1.6	15,000	10,000	13,000	15,000	9,000
Ireland	44,000	2.4	5,000	7,000	10,000	13,000	9,000
Italy	351,000	1.9	72,000	62,000	77,000	87,000	53,000
Latvia	45,000	4.5	15,000	8,000	8,000	9,000	5,000
Lithuania	41,000	2.9	12,000	7,000	8,000	9,000	5,000
Luxembourg	2.700	1.5	600	400	600	700	400
Malta	2.,900	2.0	700	500	.600	700	400
Netherlands	116,000	1.5	9,000	12,000	25,000	44,000	26,000
Poland	310,000	2.3	79,000	52,000	63,000	72,000	44,000
Portugal	110,000	2.7	24,000	20,000	24,000	26,000	16,000
Slovakia	42,000	2.0	14,000	6,000	8,000	9,000	5,000
Slovenia	29,000	3.1	7,000	5,000	6,000	7,000	4,000
Spain	433,000	2.7	79,000	73,000	97,000	114,000	70,000
Sweden	58,000	1.5	17,000	11,000	12,000	12,000	6,000

Country	Exposed	Exposed (% of employed)	< 0.5 mg/m³	0.5–1 mg/m³	1–2 mg/m³	2–5 mg/m³	> 5 mg/m³
United Kingdom	384,000	1.7	53,000	58,000	84,000	108,000	81,000
EU-25	3,600,000	2.0	747,000	597,000	763,000	897,000	563,000

Source: Kauppinen *et al.*, 2006

Of the exposed workers, 1.2 million (33%) were employed in construction, mostly as construction carpenters (see Table 22). The numbers of exposed workers in the furniture industry were 700,000 (20%), in the manufacture of builders' carpentry 300,000 (9%), in sawmilling 200,000 (5%), in forestry 150,000 (4%) and in other sectors of the wood industry < 100,000. In addition, there were 700,000 exposed workers (20%) in miscellaneous industries employing carpenters, joiners and other woodworkers. The highest exposure levels were estimated to occur in the construction sector and the furniture industry. Because exposure data was limited, there was considerable uncertainty in the estimates concerning construction woodworkers. About 560,000 workers (16% of those exposed) may be exposed to a level exceeding 5 mg/m³.

The WOODEX project also provided data on the level of exposures and the distribution of the workforce according to different levels of exposure.

Table 22: Numbers of workers exposed to inhalable wood dust, the prevalence of exposure and distribution of exposed workers (%) by industry and level of exposure in 25 Member States of the EU (EU-25) in 2000–3

Industry	Proportion of workers exposed in the industry	Exposed					
		by level of exposure					
		All levels of exposure	< 0.5 mg/m³	0.5–1 mg/m³	1–2 mg/m³	2–5 mg/m³	> 5 mg/m³
Sawmilling	76%	196,000	63,000	40,000	38,000	35,000	20,000
	Distribution by level of exposure	*100%*	*32%*	*20%*	*19%*	*18%*	*10%*
Manufacture of wooden boards	74%	92,000	32,000	19,000	18,000	15,000	8,000
	Distribution by level of exposure	*100%*	*35%*	*21%*	*20%*	*16%*	*9%*
Manufacture of builders' carpentry	71%	333,000	70,000	66,000	77,000	78,000	42,000
	Distribution by level of exposure	*100%*	*21%*	*20%*	*23%*	*23%*	*13%*
Manufacture of wooden containers	71%	57,000	12,000	11,000	13,000	13,000	9,000
	Distribution by level of exposure	*100%*	*21%*	*19%*	*23%*	*23%*	*16%*
	66%	97,000	21,000	17,000	20,000	22,000	15,000

Industry	Proportion of workers exposed in the industry	Exposed					
		by level of exposure					
		All levels of exposure	**< 0.5 mg/m^3**	**0.5–1 mg/m^3**	**1–2 mg/m^3**	**2–5 mg/m^3**	**> 5 mg/m^3**
Manufacture of other wood products	*Distribution by level of exposure*	*100%*	*22%*	*18%*	*21%*	*23%*	*15%*
Manufacture of furniture	59%	713,000	201,000	140,000	145,000	141,000	87,000
	Distribution by level of exposure	*100%*	*28%*	*20%*	*20%*	*20%*	*12%*
Building of ships and boats	11%	31,000	1,000	3,000	6,000	11,000	10,000
	Distribution by level of exposure	*100%*	*4%*	*11%*	*21%*	*34%*	*30%*
Forestry	33%	148,000	137,000	8,000	2,000	<500	<100
	Distribution by level of exposure	*100%*	*93%*	*5%*	*1%*	*0*	*0*
Construction	9%	1,190,000	92,000	173,000	285,000	388,000	254,000
	Distribution by level of exposure	*100%*	*6%*	*15%*	*24%*	*33%*	*21%*
All other employment	0.4%	709,000	118,000	119,000	160,000	193,000	118,000
	Distribution by level of exposure	*100%*	*17%*	*17%*	*23%*	*27%*	*17%*
All industries	2%	3,600,000	747,000	597,000	763,000	897,000	563,000
	Distribution by level of exposure	*100%*	*21%*	*17%*	*21%*	*25%*	*16%*

Source: Kauppinen *et al.*, 2006.

3.1.4. Identification and prevention of high exposures: Finnish 'Dirty dozen' project

FIOH has launched a project which aims to identify hazardous work activities involving chemical risks. It also aims to integrate the identification, assessment and prevention of the most serious risks caused by occupational exposure to carcinogens and other harmful chemical agents. The approach is based on available data on exposure levels and risks, and on the expert judgement of occupational hygienists and other experts from FIOH. The project started with the identification of high exposures from exposure registers and other sources of information. The sources searched for high exposures included the Finnish Register of Industrial Hygiene Measurements, the Finnish Register of Biomonitoring Measurements, the Finnish Register of Occupational Diseases, FINJEM, CAREX Finland, ASA, the Register of Occupational Accidents, the assessments of a seminar on chemical exposures, information cards on hazardous chemical tasks and various research reports on chemical exposure. This resulted in the creation of lists including hundreds of individual tasks or occupations potentially entailing a high risk of disease caused by exposure to chemical agents. These lists, with information on the level of exposure or risk of disease, were blindly ranked by the project team (eight people) and about 50 tasks with the highest rankings were described systematically in terms of exposure to harmful chemical agents, their measured exposure levels, potential health risks and observed cases of occupational diseases or accidents. During the autumn of 2013, these candidate tasks were ranked in an internet survey of occupational hygienists and other experts with good knowledge of chemical exposures. The aim was to calculate quantitative risk estimates (to the extent possible) for the worker groups performing the tasks assessed to be potentially the most harmful and to develop model solutions to prevent risks. The results will be distributed via the internet to workplaces, and labour safety inspectors will be trained to identify these kinds of risk in their daily work and to provide advice to workplaces on good preventive practices.

3.1.5. Estimating exposure to occupational carcinogens in Australia (2011–12)

In an Australian interview study, exposure prevalence was highest among farmers, drivers, miners and transport workers, as well as in men and in those individuals residing in regional areas, outside of major cities (Carey et al., 2014). This study, the Australian Work Exposures Study, aimed to investigate the current prevalence of occupational exposure to carcinogens. A random sample of men and women aged between 18 and 65, who were in paid employment, were invited to participate in a telephone interview collecting information about their current job and various demographic factors. Interviews were conducted using a web-based application, OccIDEAS. OccIDEAS is used to assess occupational exposure in epidemiological studies. OccIDEAS uses an expert exposure attribution method in which participants are asked about their job tasks and predefined algorithms are used to automatically assign exposures. The application is used to determine whether or not workers are exposed to various chemical and physical hazards (agents) based on their answers to questions about their work tasks. Responses were obtained from 5,023 eligible Australian residents, resulting in an overall response rate of 53%. 37.6% were assessed as being exposed to at least one occupational carcinogen in their current job. Extrapolation of these figures to the Australian working population suggested that 3.6 million workers (40.3%) were exposed to carcinogens in their workplace. This study demonstrates a practical approach to collecting population information on occupational exposure to carcinogens, and it documents the high prevalence of current exposure to occupational carcinogens in the general population in Australia.

The questionnaires are also known as job-specific modules (JSMs). Each JSM contains questions about particular jobs. The questions ask about the determinants of exposure to an agent rather than whether or not people are exposed to that agent. JSMs are developed by experts in occupational exposure based on the literature, talking to industry specialists and using their own experience. Currently, there are 58 JSMs in OccIDEAS, which cover the most common jobs, and one generic module for use in other potentially exposed jobs. Further modules are being developed. Results are reported by gender (the data for women are shown in Table 23) and include only those priority carcinogens with five or more workers exposed.

Table 23: Proportion of final sample and Australian working population estimated to be occupationally exposed, by carcinogenic agent, women

Carcinogen	Most common occupational groups	Sample n (%)	Population n (%)	Population 95% CI
Solar UVR	Farmer, handyperson, automobile driver	137 (6.2)	334,870 (7.9)	6.9 to 9.1
Diesel engine exhaust	Metal worker, heavy vehicle driver, miner	127 (5.7)	255,200 (6.0)	5.1 to 7.1

Shift work*	Passenger transport worker, emergency worker, nurse	104 (4.7)	192,730 (4.5)	3.7 to 5.4
Benzene	Farmer, automobile driver, animal/horticultural worker	101 (4.5)	217,200 (5.1)	4.3 to 6.1
ETS	Construction worker, miner, heavy vehicle driver	86 (3.9)	247,360 (5.8)	4.9 to 6.8
Ionising radiation	Health professional, scientist, nurse	60 (2.7)	99,940 (2.3)	1.8 to 3.0
PAHs	Farmer, emergency worker, food service worker	58 (2.6)	104,720 (2.5)	1.9 to 3.3
Silica	Construction worker, miner, farmer	27 (1.2)	43,510 (1.0)	0.7 to 1.5
Wood dust	Carpenter, farmer, printer	20 (0.9)	28,850 (0.7)	0.4 to 1.2
Formaldehyde	Animal/horticultural worker, health professional, health support worker	16 (0.7)	29,390 (0.7)	0.4 to 1.2
Lead	Miner, vehicle worker, emergency worker	12 (0.5)	31,040 (0.7)	0.4 to 1.2
Artificial UVR	Metal worker, farmer, scientist	9 (0.4)	12,670 (0.3)	0.2 to 0.6
Ethylene oxide	Electrical worker, health professional, health support worker	7 (0.3)	12,970 (0.3)	0.2 to 0.6
Trichloroethylene	Farmer, nurse, office worker	6 (0.3)	8,550 (0.2)	0.1 to 0.5

* Exposed to any one or more of seven shift work agents (light at night, phase shift, sleep disturbance, diet and chronodisruption, alcohol and chronodisruption, lack of physical activity, and vitamin D insufficiency)

Source: Carey *et al.*, 2014

3.2. Identification of groups at risk through disease data

3.2.1. Identifying occupations at risk: Nordic Occupational Cancer Study

NOCCA is a very large cohort study based on 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).

Record linkage projects such the NOCCA study, which links cancer data with exposures, provide the opportunity to simultaneously evaluate cancer patterns by occupation and occupational patterns by cancer, which is not possible using any other approach. The finding of established associations is reassuring, but, of course, revealing new leads for future investigation is the main objective of a project such as this. The large size of NOCCA allows for the study of associations between a wide range of risk factors/occupations and cancer sites/cell types, including rare types.

A number of expected associations were observed, for example mesothelioma among plumbers, seamen and mechanics, that is professions with asbestos exposures; lip cancer among fishermen, gardeners and farmers engaged in outdoor work; nasal cancer among woodworkers; and lung cancer among miners exposed to radon and silica (Blair, 2009). Some of the interesting new findings of NOCCA that deserve further attention include cases of cancer of the tongue and vagina among women chemical process workers; melanoma and non-melanoma skin cancer, breast cancer (in both men and women) and ovarian cancer among printers; fallopian tube cancer among packers and hairdressers; penis cancer among automobile drivers; and thyroid cancer among female farmers.

NOCCA also aims to link occupational titles to quantitative exposure estimates for 28 agents with the help of national JEMs (Kauppinen *et al.*, 2009). The NOCCA-JEMs were generated by a team of industrial hygienists, based on FINJEM and available exposure data and information on exposure patterns in the other Nordic countries in addition to Finland. The JEM analysis makes it possible to take into account occupational co-exposures (as confounders in research) and of taking account of lifestyle confounders (smoking, alcohol, obesity, physical exercise, parity, and so on) derived from other available datasets. The large size of NOCCA allows for the study of associations between a wide range of risk factors/occupations and cancer sites/cell types, including rare types, taking into account the wide range of exposures from different data sources as mentioned above. The first study using the NOCCA-JEM procedure concerned occupational exposure to tri- and tetrachloroethylene and the risk of NHL and cancers of the liver and kidney (Vlaanderen *et al.*, 2013). The agents included in NOCCA-JEMs as of August 2013 are presented in Table 24.

However, it is also important to consider the exclusion criteria. For the purpose of NOCCA, workers who work part-time and less than 20 hours in one job are excluded from the data. An EU-OSHA study highlighted this as a possible contributing factor to underassessment of women's exposures, as in Europe many women work part-time (EU-OSHA, 2013e). In addition, more and more workers work in multiple jobs, and although the number of hours worked in each job may be low, their overall cumulative exposure should be assessed. Such contracting patterns are frequent in services jobs such as cleaning, and even increasingly in construction.

The NOCCA study also provides information about the existing socioeconomic gradient, meaning that workers in blue-collar, low-skilled occupations are more at risk, and about factors for which the link to occupations is difficult to establish, such as static/sedentary work, which is a risk factor for intestinal cancer.

Table 24: Agents included and time periods covered by the job–exposure matrices of Denmark, Finland, Iceland, Norway and Sweden (NOCCA-JEMs)

Agent or stress factor	Unit of level of exposure	Number of periods[a]
Aliphatic and alicyclic hydrocarbon solvents	ppm	4
Animal dust	mg/m^3	4
Aromatic hydrocarbon solvents	ppm	4
Asbestos	fibres/cm^3	4
Benzene	ppm	4
Benzo(a)pyrene	µg/m^3	4
Bitumen fumes	mg/m^3	4
Chlorinated hydrocarbon solvents	ppm	4

Agent or stress factor	**Unit of level of exposure**	**Number of periods[a]**
Chromium	µg/m³	4
Crystalline silica	mg/m³	4
Diesel exhaust	mg/m³ nitrogen dioxide	4
Formaldehyde	ppm	4
Petrol	ppm benzene	4
Iron	mg/m³	4
Lead	µmol/l in blood	4
Methylene chloride	ppm	4
Nickel	µg/m³	4
Perchloroethylene	ppm	4
Sulphur dioxide	ppm	4
Toluene	ppm	4
1,1,1-trichloroethane	ppm	4
Trichloroethylene	ppm	4
Welding fumes	mg/m³	4
Wood dust	mg/m³	4
Non-chemical factors		
Ionising radiation	mSv	1
Night work	No level estimates	1
Perceived physical workload	score (0–2)	1
UVR	J/m²	1

[a] If four periods are covered, they are 1945–59, 1960–74, 1975–84 and 1985–94; if only one, it is 1985–94

Source: Kauppinen *et al.*, 2009.

The NOCCA study has a website (NOCCA Website), which provides comprehensive data on, documentation of and publications resulting from the project. Researchers interested in occupational cancer and its causes are invited to collaborate with the NOCCA study group and to use this unique data, since it provides excellent opportunities to study almost any type of cancer. The possibilities for studying the carcinogenicity of different chemical and non-chemical factors can be extended beyond those listed in Table 24 by adding occupation-specific exposure estimates of new risk factors to the NOCCA-JEMs.

3.2.2. Occupational Cancer Monitoring (OCCAM)

The Italian Occupational Cancer Monitoring (OCCAM) project originates from a collaboration between the Italian National Institute of Prevention and Safety at Work (ISPESL) which in 2010 has been incorporated into the Italian Workers Compensation Authority INAIL and the Italian National Cancer Institute in Milan (Instituto Nazionale per lo studio e la cura dei tumori). Its aim was to investigate occupational cancer risks by primary site, geographical area (province, region) and industrial sector. In addition to carrying out cancer surveillance, and allowing the identification of cases attributable to past occupational exposures, it also makes it possible to set priorities for prevention and to start legal proceedings for compensation purposes.

The OCCAM surveillance approach is based on case–control studies where the occupational histories of case subjects, obtained through an automatic linkage with social security files, are compared with those of healthy people. Data on the past employment of employees in the private sector from 1974 are available in electronic form at the National Social Security Institute (INPS). For each year of employment, the database notes the employing firm, its economic branch and whether it has white-collar or blue-collar status. Cancer cases are drawn from routinely available sources. Controls are identified by random sampling from the case base, that is the national health service archives of the areas from which the cases come and of the same calendar year(s). The random sample is stratified by age (5-year intervals) and gender. This surveillance approach has been tested using incident cases from six Italian cancer registries in the period 1990–7. Subsequently, cases have also been identified from hospital discharge records, which are available more quickly and cover almost all areas of the country (OCCAM website).

A series of case–control studies on cancer risks by industry has been carried out. The first comparison of work histories was conducted in a population-based case–control study on bladder cancer. The following sectors were associated with an increased risk of bladder cancer: the leather and shoe-making industries, transport, the rubber industry and the printing industry (Amendola *et al.*, 2005). In another study, electroplating companies in Lombardy were identified from descriptions in the social security files. The risk ratio for lung cancer among electroplating workers was elevated both for men and women. It was concluded that, although in many cases health problems had been caused by past exposure, case histories and recent acute effects indicate a present carcinogenic hazard in some Lombardy electroplating factories (Panizza *et al.*, 2012).

Oddone and colleagues found in a case-control study that the risk for female breast cancer was increased for workers in certain industries. In the case–control study, the odds ratio (ORs) for female breast cancer was modestly but significantly increased for women working in the electrical manufacturing, textile, paper and rubber-making industries. Analysis by duration of employment within sectors showed significantly increased ORs for the electrical manufacturing and rubber-making industries. After adjustment for multiple comparisons, no estimates remained statistically significant. The authors concluded that the results pointed to a possible role of exposures in the electrical manufacturing, textile, paper and rubber-making industries in the development of breast cancer. An in-depth study investigating the electrical manufacturing industry is planned (Oddone *et al.*, 2013).

OCCAM also contributes to the active search for victims of work-related cancer. Incident cases of lung, larynx and bladder cancer and leukaemia are identified from hospital records and the occupational history of the patient is automatically screened through social security records. Cases where the patient has a history of working in high-risk industries are notified to the occupational health services by Local Health Units, which identify suspected cases of occupational cancer on the basis of face-to-face interviews with patients and patients' work histories. These cases are notified to the Insurance Board for possible compensation.

In an effort to increase information and knowledge on occupational cancer risks, the OCCAM website includes a 'literature matrix', which can be searched using a combination of cancer site and industrial sector for the publications on cancer risks (Crosignani *et al.*, 2008 and 2009). The aim of this tool is to help all individuals involved in occupational medicine to identify cases in which a patient's cancer may have been caused by occupational exposure and decide about the probability of a neoplasm being of occupational origin.

Epidemiological surveillance systems for the collection of incident cancer cases due to occupational exposure have been developed in many countries. In Italy, data on malignant mesothelioma cases are collected in a national register (ReNaM) since 2002. On a regional basis, an operative center (COR) actively collects cases and defines asbestos exposure on the basis of national guidelines. Occupational history, lifestyle habits and residential history are obtained using a standardized questionnaire, administered by a trained interviewer, to the subject or to the next of kin (Marinaccio *et al.*, 2012). A similar system is apllied to the surveillance of sino-nasal cancer cases. The systematic collection of data regarding cancer cases with a relevant etiological occupational fraction could be used to identify exposed workers groups.

3.2.3. Validating exposure histories and identifying vulnerable groups: the GISCOP study

The French Scientific Interest Group on Occupational Cancer (GISCOP) was established in 2006. This is a multidisciplinary group of scientists which is committed to increasing public knowledge on occupational cancer and its prevention (GISCOP Website).

One of the main activities of GISCOP is to undertake a permanent study on the exposure histories and compensation processes of patients suffering from respiratory cancers and other possibly work-related cancers in an industrialised region near Paris (Seine-Saint-Denis). Patients in three hospitals in the region have been interviewed since 2002 and their exposure to occupational carcinogens has been assessed. In the 1,017 work histories collected in 2002–11, the most prevalent exposures identified were asbestos (29% of patients), silica (17%), PAH (14%), benzene (10%), chlorinated solvents (9%) and welding fumes (8%). The notification and compensation processes for occupational cancers are followed in collaboration with health insurance institutions (Caisses Primaires et Régionale d'Assurance Maladie). Practical rules for identifying and notifying suspected cases of occupational cancer have been made based on data from and the experiences of the GISCOP group. Information on practical solutions for preventing occupational cancer has also been developed. Jobs in which workers are most at risk include maintenance and repair and construction – encompassing a variety of tasks such as demolition and renovation and different jobs including plumbers and electricians – and cleaning and waste management (Table 25). Based on the patients' narratives and on the expertise of exposure hazard specialists, an analysis and classification of the exposed working activities was carried out to build a new database of work activities in the presence of carcinogenic products/processes. One idea was also to use the cases identified in these in-depth case studies as sentinel events to identify emerging risks and guide research (Leconte and Thébaud-Mony, 2010)

Table 25: Proportion of exposed jobs by economic sector (GISCOP)

Economic sector	Exposed (%)
Construction	86.3
Metal industry and tool manufacture	79.0
Car business and repair	75.9
Printing, chemicals and rubber industries	70.8
Clothing and textile industry	47.7

Other industries (tobacco, food, wood, furniture, electricity, etc.)	43.4
Transport and communications	42.5
Services to companies	38.0
Health, education, public administration	31.0

Source: Walters *et al.*, 2011

The difficulties and problems in the identification of carcinogen exposures and in the notification and compensation system for occupational cancers have been studied. In addition to underreporting, the results suggest social inequality in the process. Studies on the burden of work-related cancer in France and the GISCOP study were reported in English by Thébaud-Mony and Counil at the EU-OSHA workshop in 2012 (EU-OSHA, 2012). They state:

In France the official assessment of work-related cancer is based on cases compensated by health insurance, but work-related cancers are poorly represented in the list of compensated diseases. Compensation claims are dominated by asbestos-related cancer, and the process of compensation is dominated by proof of cancer causality. Consequently work-related cancer is under-notified and under-compensated (even for asbestos) and many work-related cases remain hidden. Institutional sources and the GISCOP study have provided evidence of an unrecognised work-related cancer burden in lower socio-economic classes and in women. (Counil and Thébaud-Mony, 2012).

This is also the conclusion of a report on women and occupational diseases in the European Union (Tieves, 2011).

The activities of GISCOP also include collaboration with institutions collecting and assessing exposure data (for example the SUMER Survey, French CAREX) and estimating the burden of cancer caused by occupational exposures. International collaboration is active, with partners in, for example, Brazil, Canada, Japan and the United States.

The GISCOP study in France identifies exposures via in-depth interviews with workers affected by cancer and assessment of exposure histories using social security data. The researchers also follow the recognition and compensation processes for the occupational cancer cases. The method has been used to identify sentinel cases and exposures previously not assessed, for example for women in service professions or subcontracted workers.
A socioeconomic gradient in cancer linked to chemical exposures was observed.

4. Encouraging the principles of workplace prevention in legislation

4.1. International Labour Organisation conventions and recommendations

4.1.1. International Labour Organisation conventions

The ILO convention C-139 on occupational cancer was adopted in 1974. The European Member States that have not yet ratified the convention include Austria, Bulgaria, Estonia, Greece, Latvia, Lithuania, Romania and the United Kingdom.

The convention is not limited to chemicals but rather covers all agents/factors and makes reference to the radiation convention, C-115, and to the benzene convention, C-136. It requires states to periodically determine the carcinogenic substances and agents for which occupational exposure shall be prohibited or made subject to authorisation or control, and those to which other provisions of the convention shall apply. Exemptions from prohibition may be granted only by issue of a certificate specifying in each case the conditions to be met. The identification of substances and agents has to rely on current information from the ILO or other competent bodies (ILO, 1974).

The states that have ratified the convention have to ensure that the following measures are applied.

- Carcinogenic substances or agents must be replaced by non-carcinogenic substances or agents or by less harmful substances or agents.
- The number of workers exposed to carcinogenic substances or agents and the duration and degree of such exposure must be reduced to the minimum compatible with safety.
- Measures to be taken to protect workers against the risks of exposure to carcinogenic substances or agents must be prescribed.
- An appropriate system of records must be established.
- Workers who have been, are, or are likely to be exposed to carcinogenic substances or agents must be provided with all the available information on the dangers involved and on the measures to be taken.
- Workers must be provided with medical examinations or biological/other tests or investigations during the period of employment and thereafter as necessary to evaluate their exposure and supervise their state of health in relation to the occupational hazards.

4.1.2. International Labour Organisation recommendation

In the same year, the ILO issued a recommendation (R-147) providing greater impetus to the measures ('Every effort should be made …') and describing some additional demands (ILO, 1974):

- Employers should make every effort to use work processes which do not cause the formation, and particularly the emission in the working environment, of carcinogenic substances or agents, as main products, intermediates, by-products, waste products or otherwise.
- Where complete elimination of a carcinogenic substance or agent is not possible, employers should use all appropriate measures, in consultation with the workers and their organisations and in the light of advice from competent sources, including occupational health services, to eliminate exposure or reduce it to a minimum in terms of numbers exposed, duration of exposure and degree of exposure.
- Where carcinogenic substances or agents are transported or stored, all appropriate measures should be taken to prevent leakage or contamination.

The demands are directed not only at the employers but also at the workers:

- Workers and others involved in occupational situations in which the risk of exposure to carcinogenic substances or agents may occur should conform to the safety procedures laid down and make proper use of all equipment furnished for their protection or the protection of others.

The recommendation describes the preventive measures in more detail. The competent authority may permit exemptions from the general prohibition of occupational exposure by issue of a certificate specifying in each case:

(a) the technical, hygiene and personal protection measures to be applied;
(b) the medical supervision or other tests or investigations to be carried out;
(c) the records to be maintained; and
(d) the professional qualifications required of those dealing with the supervision of exposure to the substance or agent in question.

For substances and agents subject to authorisation or control, the competent authority should:

(a) secure the necessary advice, particularly as regards the existence of substitute products or methods and the technical, hygiene and personal protection measures to be applied, as well as the medical supervision or other tests or investigations to be carried out before, during and after assignment to work involving exposure to the substances or agents in question; and
(b) require the institution of such measures as are appropriate.

The competent authority should further establish the criteria for determining the degree of exposure to the substances or agents in question, and where appropriate should specify levels as indicators for surveillance of the working environment in connection with the technical preventive measures required.

Regarding the supervision of workers' health, the recommendation states that all workers assigned to work involving exposure to specified carcinogenic substances or agents must undergo as appropriate:

(a) a pre-assignment medical examination;
(b) periodic medical examinations at suitable intervals; and
(c) biological or other tests and investigations which may be necessary to evaluate their exposure and supervise their state of health in relation to the occupational hazards.

The competent authority should ensure that provision is made for appropriate medical examinations or biological or other tests or investigations to continue to be available to the worker after cessation of the assignment.

If as the result of any action taken in pursuance of the recommendation it is inadvisable to subject a worker to further exposure to carcinogenic substances or agents in that worker's normal employment, every reasonable effort should be made to provide such a worker with suitable alternative employment.

Summary of International Labour Organisation recommendations and regulations

In summary, the ILO requires governments 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 issue of a certificate specifying in each case the protection measures to be applied,
- the medical supervision or other tests or investigations to be carried out,
- the records to be maintained, and
- the 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 worker's assignment; and
- where appropriate, specify levels as indicators for surveillance of the working environment in connection with the technical preventive measures required.

It has to be 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 (see Carcinogens Directive, Article 6) (European Commission, 2004). According to trade union sources, records are rarely requested and therefore may not be kept by employers. This applies to chemicals, and the situation with regard to other factors is probably worse.

4.2. European occupational safety and health legislation

Council Directive 1989/391/EEC of 12 June 1989 on the introduction of measures to encourage OSH improvements is often referred to as the 'Framework Directive' or the 'basic law' on OSH in the EU. It establishes the instrument of risk assessment in European OSH legislation. Employers are obliged to implement key elements such as hazard identification, worker participation, adopting adequate measures (with the priority of eliminating risk at source), documentation and periodical reassessment. (EU, 1989)

There are specific OSH directives (sometimes referred to as 'daughter directives') that set out the principles and instruments of the Framework Directive with regard to specific hazards at work (for example exposure to dangerous substances or physical agents), single tasks (such as manual handling of loads, working with visual display units), different workplaces of elevated risk (such as temporary work sites, extractive industries, fishing vessels). It also considers how these factors combine for sensitive workers, such as pregnant women and breastfeeding mothers. The individual directives define how risks are to be assessed, and the setting and measuring of limit values in the workplace. The Framework Directive states that its general provisions shall apply in full to all the areas covered by each individual directive.

The main piece of legislation regarding carcinogenic chemicals is Directive 2004/37/EC of 29 April 2004 on the protection of workers from risks related to exposure to carcinogens or mutagens at work (European Commission, 2004). It defines a clear hierarchy of specific control measures, details requirements for information and consultation of workers, and defines record-keeping. The directive requires Member States to establish arrangements for health surveillance of workers where OSH risks are present (prior to exposure and at regular intervals thereafter). If it is suspected that a worker's ill health has been caused by exposure, health surveillance of other exposed workers may be required, and the risk shall be reassessed. Individual medical health surveillance records shall be kept. This provision puts Member States in a position to gather comprehensive exposure data, which are otherwise difficult to obtain, as was outlined in the previous chapter. However, this provision is rarely implemented (European Commission, 2013a).

A revision of the directive has been pending since 2004. In 2012, the European Advisory Committee for Safety and Health at Work suggested adding ten new occupational exposure limit values (OELs) to an updated directive, namely for crystalline silica, refractory ceramic fibres, chromium VI, trichloroethylene, hydrazine, acrylamide, epichlorohydrin, 1,2-dibromoethane, methylenedianiline and wood dust (updating an existing OEL). The European Trade Union Institute (ETUI) expressed hope that this proposal would accelerate the rather slow pace of the directive revision (ETUI, 2012).

The SHEcan project has studied the impact of possible amendments to the directive (see Section 4.2.1.).

Another study, the CADimple project, studied the impact of the Chemical Agents Directive and found that, for many employers and workers, certain categories of commonly used hazardous substances are simply not perceived as 'risky' (European Commission, 2010). The authors of the project report made the following recommendations:

- support the development of sector-specific guidance (printed, interactive) and support intermediaries, for example social partners and business associations, to address their members personally (face to face);
- support enforcement strategies which strengthen and enhance the overall workplace risk prevention level in enterprises and include promotional and enforcement activities;
- use the growing need for supply chain cooperation and communication – resulting from REACH and general business developments – to promote good practice in risk assessment, risk management, instruction and substitution;

- create awareness in enterprises and at the political level by highlighting and illustrating the negative long-term effects of high and long-term exposure to chemicals.

Cherrie notes, in a study financed by HSE and the European Commission, that the Carcinogens Directive takes a ‘traditional’ approach, where the responsibility to meet minimum standards lies with the employer and the regulators enforce non-compliance. He suggests that more could be done to encourage steady progress (decrease in exposure) in specific key industries/sectors by focusing on the top ten causes of the occupational cancer burden and ensuring that exposure continues to fall by about 10% per annum (Cherrie, 2013).

Other carcinogenic factors are covered by some of the so called ‘daughter directives’ listed below.

- Directive 2009/148/EC on the protection of workers from the risks related to exposure to asbestos at work aims to protect workers´ health from risk of asbestos exposure, lays down limit values and specific minimum requirements, and it repeals the previous directives 83/477/EEC and its amendments. This Directive prohibits the application of asbestos by means of the spraying process and all activities that involve using low-density (less than 1 g/cm3) insulating or soundproofing materials and the extraction, manufacture and processing of asbestos, including products containing asbestos.
- Directive 2000/54/EC on the protection of workers from risks related to exposure to biological agents at work: this directive is designed to establish specific minimum requirements intended to guarantee a better standard of safety and health for workers exposed to biological agents at work (seventh individual directive).
- Directive 2006/25/EC on the protection of the health and safety of workers from risks arising from exposure to artificial optical radiation: this directive lays down minimum harmonised requirements for the protection of workers against risks arising from exposure to artificial optical radiation (UVA, lasers, and so on) (19th individual directive).
- Directive 2013/35/EU on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields): this directive is the 20th individual directive within the meaning of Article 16(1) of Directive 89/391/EEC and repeals Directive 2004/40/EC. It establishes minimum requirements concerning the protection of workers from risks arising from exposure to electromagnetic fields and waves.

There is also non-OSH legislation that is nevertheless relevant for carcinogenic risks in the occupational setting.

- Directive 1994/33/EC on the protection of young people at work, establishing stricter rules for the effective protection of workers under the age of 18.
- Directive 2003/88/EC concerning certain aspects of organisation of working time, applying to rest time, holidays and shift work.
- Directive 2013/59/Euratom, based on the treaty establishing the European Atomic Energy Community, lays down basic and uniform safety standards for protecting workers and the general public from dangers arising from ionising radiation.

However, these directives do not always target cancer risk factors. Some do in principle (biological agents), but awareness of cancer risks is low.

The evaluation study of the European strategy on safety and health on behalf of the Directorate-General for Employment, Social Affairs and Inclusion (European Commission, 2013b) recommended that a new strategy should focus clearly on musculoskeletal disorders, stress and occupational cancer deaths and should especially target the challenges related to the implementation of the legal framework with an explicit focus on SMEs and micro-enterprises. More specifically, the study concluded that, for many of the key occupational carcinogens, there was a need to change attitudes to the potential risks and to clearly demonstrate to employers and employees how to reduce exposures to these agents. In this respect, stakeholders at Member State level have emphasised that the European strategy is an important political landmark which has put pressure on national policy-makers to act and thus has been an important driver for the development of national strategies and national action. Some sources used in the study suggest that not only chemical but also biological, physical and organisational factors should be addressed by an overall policy that tackles work-related cancer.

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.

There is hardly any awareness that the Framework Directive and many of its daughter directives provide a basis for protecting workers from risk factors that may lead to the development of work-related cancers. This needs to be improved and the potential of the OSH legislation and its basic principles exploited further to enhance worker protection in this important area.

4.2.1. Occupational exposure limit values

Binding OELs are listed in Directives 98/24/EC, 2003/18/EC, 2004/37/EC and 2009/148/EC. They are established for a restricted number of chemical substances, namely asbestos (actinolite, grunerite, anthophyllite, chrysotile, crocidolite and tremolite), benzene, lead and its compounds, hardwood dusts and vinyl chloride.

When trying to establish OELs, a distinction is made by some countries and their expert committees between genotoxic and non-genotoxic mechanisms of action. The US Environmental Protection Agency (EPA) default assumption for all substances showing carcinogenic activity in animal experiments is that no threshold exists (or at least none can be demonstrated), so there is some risk with any exposure. This is commonly referred to as the non-threshold assumption for genotoxic (DNA-damaging) compounds. Some EU Member States do make a distinction between the two. For genotoxic carcinogens, quantitative dose–response estimation procedures are followed that assume no threshold. A threshold is assumed for the other substances, and dose–response procedures are used that assume such thresholds, where the risk assessment is generally based on a safety factor approach, similar to the approach for non-carcinogens (van der Heijden, 2003).

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 or the use of the substances cannot be avoided. Other countries (for example Germany and the Netherlands) 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 the year or over a lifetime. This corresponds to an average risk of sustaining a fatal accident (Czerczak, 2004; Wriedt, 2012; Bender, 2012). The new German approach to occupational carcinogens, which is based on this concept, is applied if substitution is not achievable/applicable. Its aim is minimisation. Its substance-independent framework concept consists of the main elements of three risk bands and a tiered control scheme. In the Netherlands, OELs are set at a level of excess cancer death of 10^{-6}, but this value must be minimised when possible (EU-OSHA, 2009a).

In a 2008 EU-OSHA survey of OELs for CMR substances, 9 out of 20 EU countries mentioned difficulties in the process of deriving OELs for carcinogenic and mutagenic substances, the most common problems being a lack of national exposure data and toxicological data and difficulty in reaching a consensus (EU-OSHA, 2009a).

The authors of the abovementioned DG-EMPL evaluation study on the European strategy on safety and health note that there is evidence of carcinogens for which no OEL currently exists and others for which the OEL could be reduced. It is estimated that appropriate action could prevent more than 100,000 occupational cancer deaths in the EU-27 over the next 60 years (DG-EMPL, 2013).

SHEcan study

In 2008, the Directorate-General for the Environment of the European Commission launched a study aimed at providing an assessment of the health, socioeconomic and environmental impacts associated with a range of policy options concerning possible future amendments to Directive 2004/37/EC (the SHEcan study). The purpose of the assessment was to enable the European Commission to initiate informed discussions with stakeholders about possible developments. The study covered the agents presented in Table 26.

The study was carried out by a consortium which was led by the UK Institute of Occupational Medicine and involved five other groups, from Finland, the Netherlands and the UK. This comprehensive study comprised the elements listed below.

- **Estimation of the number of people exposed to the 25 agents identified in the request.** Estimates were generated for exposed workers according to industry, country and gender on the basis of CAREX estimates (Kauppinen et al., 2000) and several other sources of information.
- **Estimation of exposure level by industry and country. Estimates w**ere generated, on the basis of various sources of information, on the levels of exposure.
- **Assessment of the risk associated with exposures**. Estimates of cases attributable to occupational exposure over time were generated on the basis of methodology developed in the UK (Hutchings & Rushton, 2012).
- **Assessment of the social and economic impacts of implementation and non-implementation of the proposed policy options**. This assessment considered the costs and benefits of the impacts on the health of workers potentially exposed to the substances, the economic impacts on businesses implementing changes to the directive and the costs of implementation for regulatory authorities and agencies.
- **Assessment of the potential environmental impact of the policy options on the ecosystem**. It was considered important to assess the direct effects on the environment and the impacts on humans through the environment, for example on non-workers potentially exposed through the use of products, through the air or through consumption of drinking water or food.
- **Review of the advantages and disadvantages of introducing a system for setting OELs based on quantitative risk criteria.**
- **Review of the requirements set out in the Carcinogens Directive for prevention and reduction of exposure**. This evaluation considered the suitability, comprehensiveness and effectiveness of the requirements in the directive.
- **Assessment of the impact of introducing four additional substances onto the list contained in Annex I of the Carcinogens Directive**: namely diesel engine exhaust, respirable crystalline silica, rubber process fumes and dust, and mineral oil.
- **Assessment of the impact of reducing the OELs for hardwood dust and vinyl chloride monomer.**
- **Assessment of the impact of introducing OELs for 20 listed substances**.
- **Consultation with key stakeholders in European industry, national health and safety regulatory authorities and the European trade unions**.

The results of the SHEcan study have been reported to the European Commission. The SHEcan study is unique because it not only assesses the health effects (burden of disease) of occupational exposure but also extends its scope to the socioeconomic and environmental consequences of exposure and to European regulations on exposure.

Eleven of the substances considered were accepted human carcinogens (IARC 1), four probably human carcinogens (IARC 2A) and ten were possible human carcinogens (IARC 2B). There are more than ten different types of cancer that may be caused by exposure to these substances; most commonly lung and bladder cancer.

Table 26: Chemical agents and mixtures assessed in the SHEcan study

Substance or mixture	EU Classifi-cation	IARC class	Typical exposure circumstances
Hardwood dust	*	1	Woodworking, construction, forestry
Vinyl chloride monomer	1	1	Plastics manufacture, mainly PVC
Trichloroethylene	2	2A	Solvent
Beryllium and beryllium compounds	2	1	beryllium–copper alloys, X-ray applications, nuclear industry
Chromium VI (hexavalent chrome)	2	1	Corrosion inhibitors, pigments, in metal finishing and chrome plating, stainless-steel production and leather tanning
Acrylamide	2	2A	Polymer manufacture
Rubber process fume and dust		1	Rubber manufacture and processing
Respirable crystalline silica		1	Construction, glass and ceramics, foundry industry
4,4-methylenedianiline	2	2B	Manufacture of methylene diphenyl diisocyanate and other chemicals
4,4-methylenebis(2-chloroaniline) (MOCA)	2	2A	Chemical production
1,3-butadiene	1	1	Rubber manufacture, chemical intermediate, fungicide manufacture
Ethylene oxide	2	1	Chemical production, sterilisation
Diesel engine exhaust emissions		2A	Vehicles, railways, ferries, warehouses, vehicle maintenance
Refractory ceramic fibres	2	2B	High temperature insulation
Hydrazine	2	2B	Fuels, boiler water treatments, chemical reactants, medicines
1,2-epoxypropane	2	2B	Chemical production, fumigant
1,2-dichloroethane	2	2B	Chemical production
1,2-dibromoethane	2	2A	Chemical production
o-toluidine	2	1	Dye and pigment manufacture
Hexachlorobenzene	2	2B	Banned, used as a pesticide, unwanted by-product in some processes

Substance or mixture	EU Classifi-cation	IARC class	Typical exposure circumstances
Benzo(a)pyrene	2	1	Component in tars, oils or combustion products
Mineral oils **		1	Engine maintenance, hydraulics, metalworking,
2-nitropropane	2	2B	Chemical production, solvent and fuels
Bromoethylene	2	2A	Chemical production
1-chloro-2,3-epoxypropane	2	2A	Chemical production, stabiliser

*as inhalable dust; ** as used engine oil
Source: SHEcan, 2011a and b

4.2.2. European Schedule of Occupational Diseases

The Commission Recommendation concerning the European Schedule of Occupational Diseases, published in 2003, recommends that Member States introduce national legislation on scientifically proved occupational diseases and on compensation, prevention and statistical data collection.

Diagnostic criteria for such diseases are contained in the publication *Information notices on occupational diseases: a guide to diagnosis* (European Commission, 2009). Annex I, 'European schedule', contains diseases that must be linked directly to the occupation. Annex II is an additional list of diseases suspected of being occupational in origin which should be subject to notification and which may be considered at a later stage for inclusion in Annex I to the European schedule (European Commission, 2003).

The diseases mentioned in the European schedule must be linked directly to the occupation. The Commission determines the criteria for recognising each of the occupational diseases listed in the annexes to the schedule. However, the list is more extensive than in most EU Member States.

Worker compensation systems are usually part of the social security schemes of the EU Member States. They were introduced to insure workers against the consequences of work-related injuries and relieve employers from financial liability. The organisation, funding, coverage and membership details of each system are different. They also provide compensation for acknowledged occupational diseases. A 2013 European Commission report listed the recognised cancers included in the European Schedule of Occupational Diseases. There is also a lack of harmonised criteria to recognise occupational diseases (European Commission, 2013a).

Most of the recognised cancers are diseases linked to exposure to chemicals, with the exception of shift work, which has paved the way for other organisational factors to be considered for recognition and compensation.

Trade unions make the criticism that gaining recognition of occupational diseases caused by carcinogens is often difficult in the EU (ETUI, 2007, 2011, 2014). While they consider that improved recognition of asbestos-related diseases in occupational disease compensation systems is vital, there is also a good case to be made for establishing specific funds to provide better compensation for all victims (including self-employed workers, family members who have suffered exposure in the home, and so on). The examples of France and the Netherlands, where such funds have been established, could be followed by other countries. (ETUI, 2014). In France, OSH action plans have been integrated with action plans on cancer. In the Nordic countries, there are specific exposure registers, and cancer registers, and occupational cancers are recorded as such and integrated in cancer registers.

A Danish example
The occupational diseases list in Denmark is updated continuously. Factors recognised by the IARC (groups 1 and 2A) are added with little delay. Cancer diseases caused by a substance or an exposure included on the IARC list of carcinogenic substances and exposures under groups 1 and 2A qualify for recognition when there is well-documented correlation between occupational exposure and an increased risk of the cancer disease in question in humans. Decisions by commissions on compensation claims need not to be unanimous. Thus, hurdles to compensation claims are considerably lower than, for example, in Germany (Melzer, 2014).

4.3. European Union chemicals legislation: REACH

Other important non-OSH legislation includes REACH, Regulation (EC) No 1907/2006 of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and the setting up of the European Chemicals Agency.

Under REACH, a single system for the registration, evaluation and authorisation of chemicals, information on the risks posed by substances and how they should be handled must be supplied throughout the production chain.

4.3.1. Registration under REACH

REACH continuously accumulates data on health and safety risks from the use of chemical substances. The registrant (the manufacturer or the importer), who has to provide these data to the European Chemicals Agency, also has to communicate this information to the downstream user, by providing an extended safety data sheet (SDS) with exposure scenarios containing operational conditions and risk management measures for safe use, meant to facilitate the training of workers and the risk assessment procedure. At the same time, the registrant has the right to be informed by downstream users about the applicability of the proposed risk management measures.

The first registration deadline was in December 2010, when all substances produced by a registrant in an amount greater than 1,000 tonnes per year in addition to all carcinogenic, mutagenic or reprotoxic substances (categories 1A and 1B, ≥ 1 tonne/year), and substances classified as dangerous for the aquatic environment (≥ 100 tonnes/year), had to be registered. The next deadline was June 2013 (≥ 100 tonnes/year) and then June 2018 (≥ 1 tonne/year). New substances should be notified within one month of their placement on the market. The technical dossiers submitted on registration contain information such as intrinsic properties of the substance, substance classification, usage categories and instructions for safe use. The European Chemical Agency (ECHA) publishes substance information on its website. This includes information on classification and labelling; identified uses; physical and chemical properties; toxicological properties; and safe use. ECHA has received well over 5 million notifications for more than 140,000 individual substances, of which approximately 2,800 are self-classified as carcinogens in category 1A, 1B or 2. (ECHA, 2014b)

If the substance is classified as dangerous, exposure scenarios have to be established for each use. An exposure scenario is the set of conditions that describe how the substance is manufactured or used during its life cycle and how the manufacturer or importer controls (or recommends that others control) exposure for humans and the environment. The risks associated with each use of the substance have to be evaluated in a chemical safety assessment, and adequate risk management described. All the information about ensuring safe use is forwarded down the supply chain in the form of an SDS.

4.3.2. Authorisation and restriction under REACH

Under REACH, hazardous substances can be banned if their risks are unmanageable.

A Member State, or ECHA at the request of the European Commission, can propose restrictions. Two scientific committees make an evaluation and ECHA forwards their opinions to the European

Commission, which proposes that a new restriction or a revision of an existing restriction be adopted. They can also decide to restrict a use or make it subject to a prior authorisation.

In the REACH authorisation process, the goal is to ensure adequate risk management of substances of very high concern (SVHC) (including carcinogenic substances) and to find safer alternatives. The substances are identified by the Member States' competent authorities or ECHA and placed on a candidate list, based on the Commission's recommendation. ECHA recently announced the 'Roadmap for SVHC identification and implementation of REACH Risk Management measures from now to 2020' (European Commission,2013c), which provides an EU-wide commitment to including all relevant currently known SVHCs in the candidate list by 2020. The objective of the SVHC roadmap is to develop a process for achieving this aim. It outlines a methodology for working towards this objective, with deliverables, planning and sharing of responsibilities. An implementation plan is available on the ECHA website (ECHA, 2013a).

After identification, substances are prioritised in a consultation process with the interested parties, during which they determine which uses should be subject to authorisation and which substances should be included in the SVHC list (REACH, Annex XIV). ECHA has announced the Community Rolling Action Plan (CoRAP) for 2014–16. The update contains 120 substances that will be reviewed by 21 Member States under the REACH substance evaluation process. CoRAP now includes 53 newly selected substances and 67 substances from the 2013 update. (ECHA, 2014a) After a substance is listed in Annex XIV, it cannot be used without ECHA authorisation. To obtain authorisation, the applicant must demonstrate safe conditions of use. The authorisation application includes a chemical safety report, an analysis of substitution by searching the possible alternative substances or technologies, a substitution plan and in some cases a socioeconomic analysis.

If a company intends to use an SVHC, it must apply for authorisation, although in many cases the registrant will take care of the authorisation on behalf of downstream users. In such cases, the downstream users must notify ECHA within three months of the first supply. All the authorisations are for a limited time period and are regularly re-evaluated. Manufacturing and use of substances that may pose unacceptable risks to human health or the environment can be limited or banned by the REACH restriction process. Restrictions exist for substances which do not meet the criteria of authorisation. Restrictions are set by the Commission and are always Community-wide. They can be set for all or only specific uses of the substance and there is no tonnage limit. Such restrictions are considered 'safety nets' to control risks which are not covered by other REACH processes. All the existing restrictions are included in Annex XVII to REACH (ECHA, 2013b). All restrictions that were based on the Marketing and Use Directive were carried over to Annex VII to REACH.

If the substance (on its own or as a part of a preparation or a product) is subject to restriction, companies have to comply with the restrictions and risk management measures communicated in the SDS when using the substance. If the use of a substance is banned, companies have to stop using it by the date specified in Annex XVII to REACH. Information on whether the substance is subject to restrictions can be found in Section 15 of the SDS.

Registration under REACH is expected to improve the overall quality of the database on substance hazards. The tonnage aspect is problematic, however, as REACH does not require data for chemicals produced in small quantities (less than 10 tonnes annually). In addition, many major exposures identified, even in the chemical field, are generated by work processes and will not be tackled by REACH legislation (for example diesel exhaust, welding fumes, silica and endotoxins); many exposures are complex mixtures (rubber chemicals, nitrosamines, PAH, mineral oils, solvent mixtures) or carcinogenic elements are generated when using these mixtures (as in the case of nitrosamines in cutting fluids, for example). Non-chemical carcinogens are not covered by REACH. Furthermore, REACH information is mainly generated from chemical testing or equivalent methods, such as structure–activity relationships and modelling, and not based on epidemiological findings.

REACH is also directly linked to the Regulation on classification, labelling and packaging of substances and mixtures (CLP) (European Commission, 2008a), which establishes the hazard and precautionary statements and pictograms that are an important source of information for workplace protection.

The European Union classification of carcinogens is contained in the CLP regulation, in line with the Globally Harmonized System (GHS) scheme. It consists of category 1, substances known (1A) or presumed (1B) to be human carcinogens, and category 2, suspected human carcinogens.

REACH and CLP should be properly integrated with OSH legislation, for example by allowing access to data generated by REACH and CLP (especially in cases of self-classification, in contrast to harmonised classification at EU level), through better awareness and through exchange of information on exposure situations with OSH stakeholders. Advice provided in SDSs and exposure scenarios should be realistic, taking account of the special provisions of the hierarchy of control measures.

4.3.3. Derived no-effect levels required under REACH

Under REACH there is a requirement for health-based derived no-effect levels (DNELs) to be established for occupational (and non-occupational) exposure to chemicals produced or imported into Europe in annual quantities above 10 tonnes. The DNELs apply to all routes of exposure (oral, dermal or inhalation) and all populations (workers, consumers, people indirectly exposed like children or pregnant women). They are used to establish risk management measures that must be communicated to the downstream users.

A study comparing OELs and derived no-effect levels (DNELs) found that DNELs could be far below or above OEL values (Schenk & Johanson, 2011). These discrepancies may create confusion in terms of legal compliance, risk management and risk communication. A German study conducted an initial review of the DNEL list of German Social Accident Insurance (DGUV, no date), which has facilitated virtual access to many DNELs relevant to the workplace. The authors found a number of discrepancies and shortcomings, such as DNELs for substances without a known toxicological effect threshold or an excessively large number of identical DNELs for the systemic and local effects of a substance (Nies *et al.*, 2013).

Derived Minimal Effect Levels (DMELs) were defined in guidance documents of ECHA for REACH (ECHA 2012). No DNEL can be derived for non-threshold mutagens/carcinogens as it is assumed that a no-effect-level cannot be established for these substances (either because there is no threshold or the threshold level cannot be determined). In such cases, and assuming that there are data allowing it, the registrant should develop a DMEL (derived minimal effect level), a reference risk level which is considered to be of very low concern. DMEL derived in accordance with the guidance should be seen as a tolerable level of effects. However, they have no direct legal basis in REACH. Their character as risk-based exposure limits for the genotoxic effects of substances and their derivation is recommended only in the guidance documents of the European Chemicals Agency. Nevertheless they are required to be supplied when a substance is registered for which no toxicological threshold mode of action is to be assumed, and therefore no Derived No Effect Level (DNEL) can be established. In a critical evaluation by the Austrian workers compensation Board AUVA, it was found that DMEL may represent a wide range of remaining risk levels, in some cases DMELs corresponded to a working lifetime risk of up to 1.8% (Püringer, 2011).

A threshold dose/concentration cannot be identified when genotoxicity is the underlying mechanism for the toxicity of a substance. In such cases, a DNEL value cannot be derived, and instead a qualitative risk characterisation approach is applied, this uses qualitative measures of the potency of the substance to develop exposure scenarios with appropriate risk management measures and operational conditions. This approach, used in particular for high hazard substances, is somewhat similar to the ALARA principle (as low as reasonably achievable) originally used in the area of radiation protection (ECHA, 2012). However, this not in line with the hierarchy of control measures as foreseen in the carcinogens directive. It is all the more necessary to apply a precautionary principle when considering prevention measures in the case of carcinogens (see also the following chapter). However, this creates problems both for companies and for authorities, as clear guidance may be lacking. The concept of health- or risk-based exposure limits (as described in section 4.2.1.) is applied instead in some countries.

4.4. Other regulations

4.4.1. Tobacco smoke

A Council Recommendation on smoke-free environments was adopted, as the result of consultation and legislative process, on 30 November 2009 (European Council, 2009), calling on Member States to act in three main areas:

- Adopt and implement laws to fully protect their citizens from exposure to tobacco smoke in enclosed public places, workplaces and public transport, within three years of the adoption of the Recommendation
- Enhance smoke-free laws with supporting measures such as protecting children, encouraging efforts to give up tobacco use and pictorial warnings on tobacco packages.
- Strengthen cooperation at EU level by setting up a network of national focal points for tobacco control.

In February 2013, the Commission published a report summarising the state of implementation of the Council Recommendation on smoke-free environments of 2009 (European Commission, 2013e). The report finds that:

- All EU countries have adopted measures to protect citizens against exposure to tobacco smoke. National measures differ considerably in extent and scope. The strictest measures were introduced by Ireland, the UK, Greece, Hungary, Bulgaria, Malta and Spain.
- Enforcement seems to be a problem in some Member States. Complex legislation (i.e. legislation with exemptions) is found to be particularly difficult to enforce.
- The actual exposure rates for EU citizens dropped from 2009 to 2012, e.g. for citizens visiting bars and pubs the exposure rate dropped from 46% to 28%.
- Belgium, Spain and Poland are examples of countries where the adoption of comprehensive legislation led to very significant drops in tobacco smoke exposure within short time period.
- The health effects of smoke-free legislation are immediate and include a reduction in the incidence of heart attacks and improvements in respiratory health. The economic effect of smoke-free legislation is positive or neutral.

Most of the legislative acts are through tobacco acts and public health regulations. In some instances, the responsible authorities for health and safety at work are involved in enforcement.

A consultation of the European social partners on the protection of workers from risks related to exposure to environmental tobacco smoke at the workplace has also been carried out in 2008 (European Commission, 2008c)

EU-OSHA has supported the Commission´s work by designing awareness-raising materials and running awareness-raising activities. The materials include a dedicated webpage, videos and short guidance documents tailored to different target groups (EU-OSHA, 2013a-d).

Some practical guidance is also available for workplace risk assessment. A risk assessment guidance tool was developed in Ireland by HSE (Health Service Executive, 2009) and EU-OSHA has included the issue in its practical guidance and checklists, for example for the hospitality sector.

4.5. Principles of workplace prevention

4.5.1. The importance of the precautionary principle

In a 2011 article, Melnick and Huff note that arguments such as 'people are not rats or mice' or that 'doses used in animal studies or occupational exposures are much higher than exposures to the general population' do not take into account the fact that the agent under consideration is a carcinogen. Melnick and Huff argue for a precautionary approach, and strongly oppose recommendations to delay primary prevention practices until additional data are available, as this does not provide reassurance or health protection to exposed populations. Instead, they feel that it is essential to adopt an attitude of responsible caution, in line with the principles of primary prevention. They suggest, that this may be the only way to prevent unlimited experimentation on the human species (Melnick & Huff, 2011). According to the Carcinogens Directive substances without a direct evidence of carcinogenicity in humans can be covered by the stricter provisions of this Directive. They apply when a substance or mixture meets the criteria for classification as a category 1A or 1B carcinogen.

A precautionary approach is needed, where uncertainties such as dealing with mixtures or having insufficient data are identified. Such an approach needs to be developed by researchers and professionals, and should be integrated into guidelines, tools and possibly SDSs.

Such a precautionary approach also needs to consider changes in the world of work, such as the growth in subcontracting, temporary work, multiple jobs, working at clients' premises with limited possibilities for adaptation, increasingly static work, the move from industry to service sectors, growth in the numbers of women in exposed occupations, atypical working times and increasing multiple exposures (EU-OSHA, 2012).

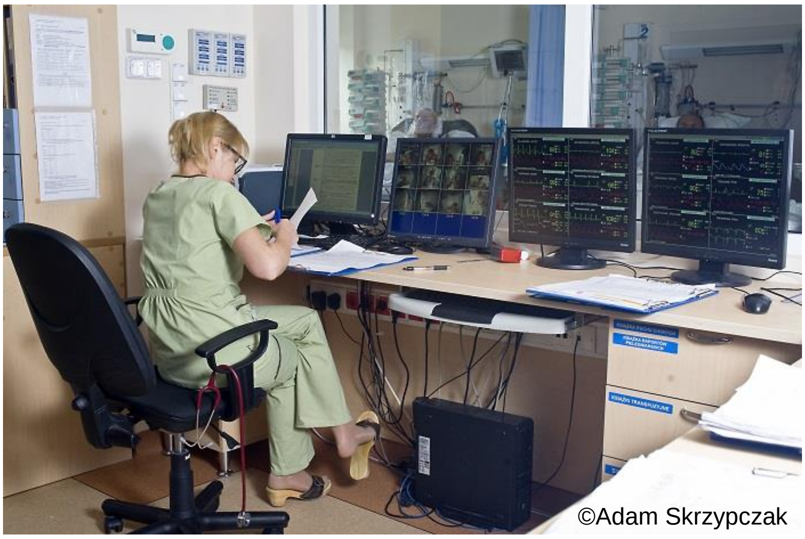
Hutchings and Rushton present a method for estimating the future burden of occupational cancer that makes it possible to test the effects of a range of potential interventions. The method is adaptable to situations where data, in particular exposure level data, are sparse; it is most robust in allowing comparison between intervention effects, and where a broad estimate of future burden across exposures is required. It can also be adapted to assess the impact of policy on specific industries, and to use higher quality exposure data if available. Preventive measures may include better exposure standards, improvements in enforcement and higher compliance rates (Hutchings & Rushton, 2011). In 2010 Rushton reported to HSE that an estimated 2,000 breast cancer cases and around 550 breast cancer deaths a year could be attributable to shift work. HSE has commissioned the University of Oxford to undertake an extensive study on the relationship between shift work and chronic disease, with a focus on shift-working patterns in relation to cancer and other chronic conditions in men and women. The study will be completed by December 2015 (HSE, no date).

Prevention measures in companies and organisations have to be based on sound OSH management. Objectives, responsibilities, qualifications, training and communication are important features of such management systems, which must guarantee comprehensive risk assessment as well as implementation and evaluation of related measures.

Risk assessment must involve the affected workers, as they have practical knowledge of the working processes, the related conditions and the substances/agents in use. Preventive measures have to be derived based on the assessment. However, smaller companies are especially advised to seek guidance from external experts, such as labour inspectors, insurance officers and occupational physicians, as carcinogenic substances, agents, factors and conditions form a broad and often disputed category.

The selection of specific measures depends firstly on the type of substance or factor: chemical substances need different measures from those required for biological, physical or work organisational factors. Emerging risks, such as exposure to nanomaterials and EDCs, often require a precautionary approach.

Clapp and colleagues demand a new cancer prevention paradigm, which should be based on an understanding that cancer is ultimately caused by multiple interacting factors (Clapp, Jacobs & Loechler, 2007). The old paradigm was based on what they call 'dubious attributable fractions'. This new cancer prevention paradigm demands that exposures are limited to avoidable environmental and occupational carcinogens in combination with additional important risk factors such as diet and lifestyle. This implies introducing a healthy diet and lifestyle into the occupational setting for example during night or shift work, at mobile workplaces, and so on, and making it possible for workers to adapt their working conditions accordingly.



Emergency ward

4.5.2. Avoidance and substitution

The most effective measure is the avoidance of the dangerous substances/factors or the substitution by harmless substances/factors or processes. However, this can be very difficult in practice, especially in smaller companies. Studying hazardous chemicals, Ahrens and colleagues concluded that companies would rather implement technical and personal protection measures than make efforts to eliminate or reduce hazards (Ahrens *et al.*, 2006). The authors found that efforts by companies face a number of challenges:

- The attitude in companies is that it is preferable never to change an existing process, as process changes may bring about uncertainties.
- Hazard elimination or reduction is not a high priority either in companies or practical governance.
- Dealing with current problems is already too laborious; companies wish to avoid creating additional problems caused by an unnecessarily innovative approach.
- Companies feel uncertain about risk assessments: a change in an existing process may result in a shift of risks.
- Substitutes may not have been tested extensively in practice.
- Integration in the production chain necessitates an innovation beyond what the company can implement.
- Technological or financial difficulties.

The authors have identified influential factors, including society, public policy, regulation and market forces, that must all play a role to overcome these difficulties.

The European Commission commissioned a study on the practical implementation of substituting chemicals in workplaces across the EU, which was published in 2012. The focus is on substitution as a risk management measure to reduce risks to workers' health and safety resulting from chemicals in the workplace. Throughout the project, substitution was approached from a risk-management perspective. The authors found that the main substitution drivers are legislation, pressure from the supply chain and pressure from the company. They identified the need for common guidance on substitution across the EU and developed a common approach, which they presented as a guidance document. The primary target audience of Part I, '"Practical guidance"', is companies with limited knowledge of or experience with chemical risk management. Two processes were developed: one simplistic, suitable for easier types of substitutions (known alternatives, customer benefit); the other was more detailed, and is suitable for more difficult evaluations. For the latter, the authors see the challenge not in constructing a step-by-step sequence, but in paring it down to its essential core and linking each step to existing best practices, tools and databases (European Commission, 2012).

DG-EMPL published practical guidelines on the protection of the health and safety of workers from the risks related to chemical agents at work. The guidelines include a chapter on substitution, stressing the top-priority areas and presenting a number of good practice examples. (European Commission, 2006)

EU-OSHA has published a concise factsheet on the elimination and substitution of dangerous substances (EU-OSHA, 2003).

- **Substitution databases**

The SubsPort (Substitiution Support Portal) project has developed an internet portal that constitutes a state-of-the-art resource on safer alternatives to the use of hazardous chemicals. It is a source of information on alternative substances and technologies, as well as tools and guidance for substance evaluation and substitution management.

The portal is intended to support companies in fulfilling EU legislation substitution requirements, such as those specified under the REACH authorisation procedure, the Water Framework Directive and the Chemical Agents Directive. Stakeholders such as authorities, environmental and consumer organisations and scientific institutions will benefit from the portal.

The project also aims to create a network of experts and stakeholders who are active in substitution. This network should assist in developing the portal's content and promoting it, as well as ensuring sustainable updates and maintenance. This will contribute to the project's goal of raising awareness and promoting safer alternatives. Furthermore, training on substitution methodology and assessment of alternatives is provided through members of the network. The portal is publicly available at: http://www.subsport.eu/.

In 2006, the French Ministry of Labour commissioned the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) to (i) carry out a study on the effectiveness of category 1A and 1B CMRs and (ii) develop a tool to promote substitution. This has become a permanent activity of ANSES, and a website has been created: substitution-cmr.fr. The information available in the portal has mainly been collected from surveys of companies on their use of CMR and substitutions. The database is enriched with examples from different sources. By the end of 2013, over 350 examples of alternatives to more than 100 CMR substances were available on the website. The data were collected from 500 companies.

4.5.3. Technical measures

Technical solutions would include encapsulation and exhaust systems. However, systems can be damaged; they may fail and need to be switched off for repair and maintenance. Organisational solutions – for example allowing only qualified workers to conduct the work and having strict supervision in place – often rely on personal protective equipment (PPE). PPE may need to be used in conjunction with measures to increase safe behaviour. Experts found, for example, that welders are often reluctant to use respirators and that workers sometimes deliberately disable safety appliances. A comprehensive approach is required to achieve safe behaviour: management and supervisors must set a good example, there must be a no-blame culture and swift action on feedback proposals must be demonstrated. Measures aiming to improve the safety behaviour of workers should include peer observation and peer discussion. All measures (including technical measures) must be accompanied by proper instructions and training.

Sectors and job types also influence the measures to be applied, as do process scenarios, such as working in confined spaces or using varying amounts of substances at different temperatures (Greenwald and Warshaw, 2003).

Table 27 gives an overview of the measures recommended in the literature studied, as well as possible tools, guidance, and so on.

Table 27: Examples of preventive measures

Type of measures	**Examples**
Chemicals	Agreed codes of practice, e.g. the German TRGS (BAuA, 2013) Sectoral guides
Avoidance, substitution with harmless agents	Substitution databases and tools, e.g. SubsPort.eu, substitution-cmr.fr
Technical measures, incl. substitution with less hazardous agents	Closed system, e.g. airtight metal cleaning plant using perchloroethylene Specific local extraction systems Cleantool.org
Organisational measures	Access system for specifically trained workers
Personal measures	Respirators with specific filters
Pesticides	
Avoidance, substitution with harmless agents	Organic farming
Technical measures, incl. substitution with less hazardous agents	Integrated pest management Using application procedures and devices that reduce exposure
Organisational measures	Reducing the number of workers exposed, avoiding exposure for workers who do not use pesticides, decontamination procedures, proper procedures for storage and cleaning of substances and equipment Maintenance of application devices, machinery and protective equipment
Personal measures	PPE, protective clothing, hygienic procedures for separating and cleaning contaminated clothing
Pharmaceuticals	Best practice examples described in the Commission guideline for the health-care sector (European Commission, 2011)
Emerging factors, nanomaterials	Good practice examples at EU-OSHA website (EU-OSHA, no date) Precautionary approach needed
Avoidance, substitution with harmless agents	Avoid or reduce use Substitution databases, e.g. SubsPort.eu, substitution-cmr.fr
Technical measures, incl. substitution with less hazardous agents	Closed systems

Type of measures	Examples
Organisational measures	Cordoning off of areas, restricted access
Personal measures	Recommended respiratory protective equipment Precautionary approach needed
Biological factors	Commission guideline for the health-care sector (European Commission, 2011) Specific measures for specific agents Agreed codes of practice, e.g. TRBAs (BAuA, 2012a) (BAuA, 2012b)
Avoidance, substitution with harmless agents	Only applicable where there is deliberate use of the biological agent; however, work procedures can be adapted to limit unintentional exposures and leaks
Technical measures, incl. substitution with less hazardous agents	Closed systems, engineering controls, capture at the source of emission Room ventilation and air-conditioning measures, binding dust using mist technique Enclosed transport routes for dust-producing bulk materials
Organisational measures	Good hygiene practices, use of a cleaning and hygiene plan Restricted access Black/white areas, spatial separation of polluted and unpolluted areas
Personal measures	PPE, proper clothing, vaccination
Physical factors	
Sedentary work	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, e.g. through breaks and reorganisation of work procedures
Radiation	Closed, insulated systems Cordoning off areas, restricted access Recommended PPE Prevention of radon exposure in radon-prone areas and new constructions

Type of measures	Examples
Psychosocial factors	
Avoidance, substitution with harmless agents	Reduction or avoidance of stress through establishment of a beneficial social climate
Technical measures, incl. substitution with less hazardous agents	Reduction of stress through optimal equipment and design of working procedures and rooms
Organisational measures	Improved work organisation (participation of workers)
Personal measures	Training in methods for coping with stress, improving social climate Health promotion, avoidance of negative stress coping strategies (smoking, drinking, etc.)
Shift work, night work	
Technical and organisational	Shift work design according to scientific recommendations and best practice examples Design of schedules, limitation of years worked in shifts, health promotion, organisation of rest periods Rest and eating facilities, making appropriate meals available
Personal measures	Training, instructions regarding eating habits and rest periods
Combination of different risk factors	Precautionary approach needed Holistic risk assessment JEMs that address all risks Approach by occupations

TRGS, Technical rules on hazardous substances; NIOSH, US National Institute for Occupational Safety and Health;

Source: Compiled by the authors

4.5.4. Guidelines and tools

Ideally, the risk assessment help offered to SMEs should be sector-specific and cover all factors, including chemicals and biological/physical/psychosocial agents. In order to allow continuous updates, the tools should be web-based and interactive. The measures proposed should also take into account the precautionary principle when sufficient data are not yet available. EU-OSHA and partners are currently developing such a tool: OiRA – Online Interactive Risk Assessment. It is a huge task, and it will take time until this tool is available for all sectors and in all Member State languages. Meanwhile, we have tools and guidelines that cover important parts of the aforementioned aspects.

There are two types of tools available for chemicals, Stoffenmanager and GISBAU.

Stoffenmanager was established by three Dutch institutes. It is available on the internet in three languages at www.stoffenmanager.nl. Users must enter data themselves from SDSs. After entering all required information, they receive proposals for protective measures that will keep the risks at an acceptable level. However, the measures need critical reflection, as some SDSs may be incorrect or incomplete (Suleiman and Svendsen, 2014; Singh *et al.*, 2014) and many SDSs do not mention nanomaterials, biological agents or EDCs. Furthermore, may be difficult to establish what hazardous materials, such as fumes, dusts, and mould, are generated during work processes. This situation should improve as the system stores substance/mixture/process information, and some producers voluntarily include nanomaterial information in their SDSs.

GISBAU was established by the German accident insurance association for the construction sector, a sectoral organisation of DGUV. It is available on the internet in German only, and there is a version for smartphones (see www.gisbau.de). The users can select the type of chemical or mixture they are working with and find information about the necessary protective measures. This system has the advantage that experts scan the available SDSs, so that errors (such as incorrect SDSs) and user oversights are ruled out. In addition, scientific developments and possible precautionary measures can be quickly weighed up by the experts. Standardised guidance documents provide information on exposures when carrying out certain tasks (based on exposure measurements), information on DNEL and OEL, and possible preventive measures. Maintenance of this system is laborious compared with Stoffenmanager, however, and there are, therefore, only few of tools of this type available.

As part of a project to enhance the use of electronic media, a new feature has been developed: SDBtransfer is a continuous electronic process for the electronic exchange of safety-related data in the supply chain of the construction industry. Although the vast majority of companies now use specialized software for the preparation of safety data sheets, paper-based transmission remains the preferred option for data transfer in the supply chain. A standard for electronic transmission of such data and safety information is still missing. With the establishment of a digital safety data sheet existing hurdles could however be eliminated and important contributions be made to reduce costs. In particular, SMEs would be relieved with administrative tasks (SDBtransfer, 2014).

In 2013, the French National Cancer Institute (INCA) launched new tools for health professionals for the prevention of occupational cancers:

- Cancers Pro Actu is a quarterly newsletter on the prevention of occupational cancers. It presents a selection of tools and recently published internet resources (usually free). It is available only in French (INCA, 2013a). The bulletin number 6, for example, offers short descriptions of Thorium-252 and of electromagnetic fields, providing links to ministry sites which list and discuss health effects.
- Cancers Doc Pro is a guide to resources on the primary prevention of occupational cancers. It offers a selection of practical tools and media that can be used by occupational health-care professionals. It is available only in French (INCA, 2013b).

4.6. Back-to-work policies

Because of improved identification and treatment, more workers now return to work after cancer treatment. However, EU-OSHA concludes that there are few targeted rehabilitation and return-to work strategies, and these were originally developed for other work-related health conditions (such as musculoskeletal disorders). Workers who have suffered work-related cancer may need specific measures to protect them from re-exposure to the same risks as before, or to adapt conditions to their physical abilities. The first days after the return to work are crucial, so enterprises should be prepared to adapt working conditions to specific conditions from an early stage. Rehabilitation into work is less accessible for women than for men. Strategies need to target both women and men, and include temporary and part-time workers. An ageing working population will also have a higher proportion of chronic diseases, and strategies need to be developed to keep people in work with decent working conditions for all. A thorough assessment is needed. Cancer risk factors such as shift work are a particular challenge for such workplace adaptation. At an EU-OSHA conference in 2012, it was recommended that information on back-to-work practices should be collected, as is done for mental health and MSDs (EU-OSHA, 2012).

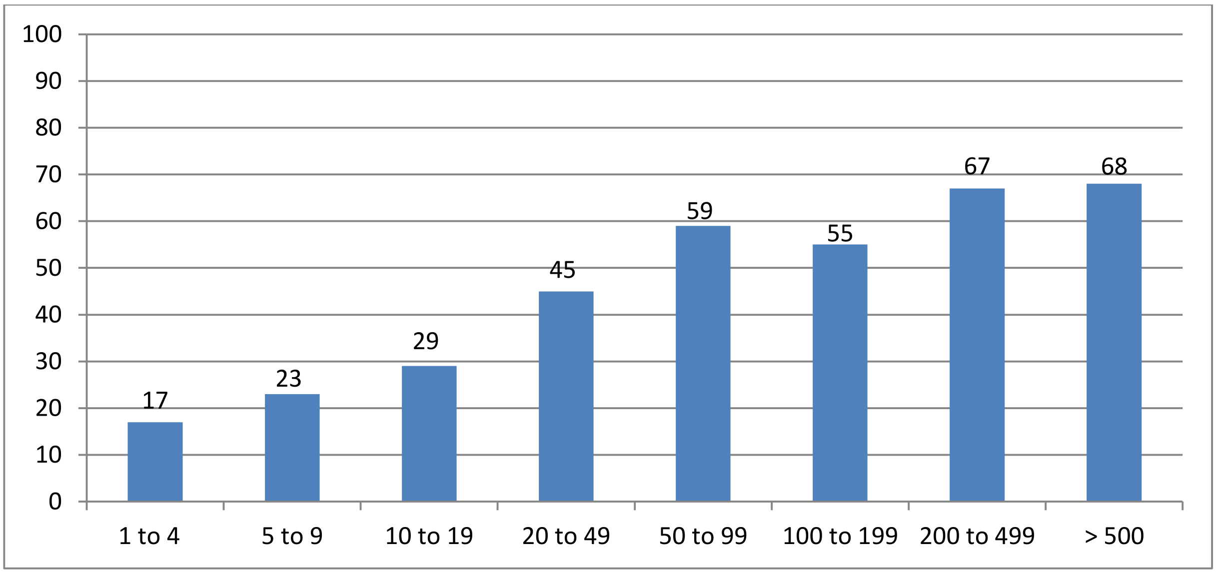
5. Examples of national policies and strategies

5.1. France

The inventory CMR 2005 is a summary of a survey conducted by INRS in France in the course of 2005, at the request of the Ministry of Labour, to assess the use of CMR substances (Vincent, 2006). It has been used to support other national activities regarding occupational exposure to CMR. This database included 380 factsheets. For each CMR substance, it provided information on the quantities produced, exported and imported, uses, means of substitution and, finally, estimates of the numbers of workers exposed. National and European statistical data and information collected from a representative sample of 2,000 establishments in 30 industries were analysed to estimate the annual consumption of 324 CMR agents and hundreds of petrochemical derivatives. The results of this survey indicate that 4.8 million tons of CMRs were consumed in France in 2005. For 10 chemicals, CMR consumption exceeded 100,000 tons per year. Industries, including the pharmaceutical and chemical industry, are the main consumers of primary CMR chemicals, although CMRs are widely used in many sectors because they are present in formulations of industrial products. The survey also found that the production of auramine was non-existent in France, while other restricted work processes were still in use but involved a limited number of workers.

A subsequent 2006 inspection campaign (Certin *et al.*, 2007) on the use and circumstances of use of CMR substances in companies focused on four industries: mechanical industry, plastics, the paints and varnishes sector, and production of refractory ceramic fibres. It focused on a limited number of products: trichloroethylene, lead compounds, phthalates, chromate MbOCA and refractory ceramic fibres. Nearly 2,000 companies were visited, of which 900 reported using CMRs. The survey aimed to identify business practices such as identification of CMRs, risk assessment approach, substitution, and prevention measures. Although a majority of the enterprises carried out and documented a risk assessment, only a limited number had actually specifically raised the topic of exposure to CMR substances (see Figure 7). With regard to substitution, for degreasing, this took place largely in relation to trichloroethylene; substitution of other CMRs was limited. Enterprises did not consistently follow the requisite control measures, especially with regard to the demarcation and signage of areas where CMRs were used and record-keeping on exposures. Maintenance work, which potentially leads to higher exposures, was not generally considered.

Figure 7: Percentage of enterprises with a risk assessment that addressed CMRs, by size of enterprise (number of employees)



Source: Certin *et al.*, 2007

In 2007, AFSSET (now ANSES) identified a list of 82 substances (CMR category 1 or 2) primarily to assess the possibilities for substituting them. The SIRIS (Système d'Intégration des Risques par Interaction des Scores - System of Integration of Risks with Interaction of Scores) tool supports decision-making based on the following criteria:

- CMR classification in the European Union – carcinogenic potential (classification C1 to C3), mutagenicity (classification M1 to M3), and/or toxicity for reproduction (ranking R1 to R3).
- Annual consumption in France (according to the inventory of CMR substances developed by INRS in 2005).
- The number of workers potentially exposed, or 'exposabilité' . 'Exposability', meaning the number of workers potentially exposed, rather than actual exposure, according to the 2005 CMR inventory mentioned above. In the context of the inventory of, a worker 'potentially exposed' is one who directly manipulates a CMR agent or is working in a workshop where it is used, without prejudging the actual level of exposure.

The prioritisation of substances was based on hazard, consumption and exposability criteria. A total of 82 substances were ranked in order of their SIRIS scores. Of these, 23 substances were studied.

A similar concept has been used to develop a general method for identifying and prioritising substances of concern for priority actions in the framework of the Second National Health and Environment Plan by INERIS, the French National Competence Centre for Industrial Safety and Environmental Protection, (INERIS, 2010).

In conjunction with government programmes – Health at Work 2010–2014, for example – the Labour General Directorate DGT in partnership with the National Agency for Health and Safety (ANSES) conducted a campaign in late 2010 to reduce workers' exposure to hazardous substances in the vehicle repair and industrial cleaning sectors. It was discovered from the almost 4,000 company visits during the campaign that many companies had no chemical risk assessment document: 44% of small companies, 23% of medium companies, and 5% of large companies. Eighty-two CMR substances were identified, including exhaust fumes, solvents, paints/isocyanates and petrol/benzene. The partners initiated a search for substitutes to replace the toxic products and reduce exposure. The following general results were noted by the campaign manager. The inspection campaign increased chemical risk assessment awareness in SMEs with fewer than 50 workers, which led to more effective implementation of regulatory requirements. Companies that had previously been inspected understood the risks much better – an important argument for conducting inspections of small companies more often. Another important outcome was an agreement with two motor vehicle repair federations to reduce the use of hazardous substances (Pretto, 2012).

ANSES has also issued expertises regarding the effects of shift work and is following work on pesticide exposure and health effects in farmers. Two study areas are worth mentioning:

- Health risks among farmers. The AGRIculture and CANcer cohort is a large prospective cohort of subjects in agriculture studying cancer among active and retired males and females, farm owners and workers, living in eleven areas of France with a population-based cancer registry. . In January 2008, 180,060 individuals (54 % males, 54 % farm owners, 50 % retired) were enrolled with a postal questionnaire. Data on occupational history and agricultural exposures during lifetime on 13 types of crops and 5 types of animals were collected by the enrollment questionnaire. Analyses have focused on causes of death and specific types of cancer, such as prostate cancer (Lemarchand et al., 2014)
- The investigation into cancers potentially influenced by night shift work:
    - Data on lifelong occupational history collected as part of a population-based study conducted in France was used to investigate the role of night work in breast cancer in the CECILE study (Menegaux, 2013).
    - The EPIdemiological study of Prostate CAncer (EPICAP) is an ongoing population-based case–control study specifically designed to investigate the role of environmental and genetic factors in prostate cancer, with a particularly focus on the role of circadian disruption, chronic inflammation, hormonal and metabolic factors in the occurrence of prostate cancer (Menegaux *et al.*, 2014).

- The ARDCO Asbestos Related Disease Cohort focuses on asbestos. A questionnaire-based study (NETKEEP InCA) focuses on exposure histories of patients with a bronchial cancer.
- While not being focused specifically on occupational cancer, sentinel systems based on case study reports of specific health problems such as the RNV3P database in France also provide information on emerging cancer-exposure relationships.

To bolster notoriously scarce resources for labour inspections, Member States could follow the Swedish example: Sweden has a very interesting and unique system of regional safety representatives for small workplaces. They are appointed by the trade unions and can inspect SMEs. The costs for the inspections are partly covered by the government.

5.2. Canada

A tripartite initiative established the Canadian Centre for Occupational Health and Safety (CCOHS) in 1978. This not-for-profit federal department corporation is run by representatives of government, employers and workers to ensure a balanced approach to OSH. CCOHS promotes the total well-being – physical, psychosocial and mental health – of working Canadians. It provides information, training, education, management systems and solutions that support health, safety and wellness programmes. The centre operates a bilingual website in English and French. It offers a question and answer service, publishing the most interesting ones. Users can search the INCHEM database of internationally peer-reviewed information from intergovernmental organisations, find SDSs and search the relevant Canadian legislation.

Established in 2009, the Occupational Cancer Research Centre (OCRC) is a partnership uniting research, health care, workplace safety, labour and industry groups. It is jointly funded by Cancer Care Ontario, the Workplace Safety and Insurance Board and the Canadian Cancer Society, Ontario Division, and was developed in collaboration with the United Steelworkers. The OCRC grew out of a recognised need to re-emphasise research on the causes and prevention of occupation-related cancers after decades of diminished effort in most countries. It works to fill the gaps in knowledge of work-related cancers, using these findings to inform preventive programmes to control workplace carcinogenic exposures and improve the health of workers. Some of the centre’s activities are presented in the following paragraphs.

5.2.1. *Occupational cancer surveillance using the 1991–2006 Canadian census mortality and cancer cohort*

Although Canada registers every new cancer that is diagnosed, information on occupation and workplace exposures is not included in these records. The goal of this project is to identify specific occupations, industries or exposures that lead to an increased risk of cancer, by using a database containing information from the 1991 long-form census linked with the Canadian Cancer Registry data. Relationships of interest include:

- lung cancer in welders
- occupations and ovarian cancer
- cancer among woodworkers
- cancer among firefighters and police
- shift work and cancer
- cancer in agricultural workers
- occupational physical activity and colorectal cancer

Statistics Canada linked data from the 1991 long-form census to the Canadian Cancer Registry, a national database created with data from all the provincial and territorial tumour registries. The resulting database includes 2.7 million people. The analyses of this database aim to identify whether there is an increased risk of cancer associated with suspected carcinogens, and to see whether some groups of people with the same job or in the same industry have an increased risk (OCRC, 2014a).

5.2.2. *Cross-Canada Study of Pesticides and Select Cancers*

Over the past several decades, incidence rates of non-Hodgkin's lymphoma (NHL) have been increasing worldwide, including in Canada. Although the reasons for this increase are not clearly understood, lymphomas, multiple myeloma and soft-tissue sarcomas have been associated with farming and some specific farm exposures. A Canadian population-based case–control study (Cross-Canada Study of Pesticides and Select Cancers (CCSPH)) in six provinces was designed to evaluate specific agricultural exposures that might be involved.

In addition, researchers from the US National Cancer Institute and the OCRC are currently joining the CCSPH dataset with three other datasets of similar case–control studies that were conducted in four American states during the 1980s. This initiative is called the North American Pooled Project. It is expected to provide an opportunity to overcome some of the challenges of previous studies, particularly the small number of cases that have limited the strength and consistency of associations (McDuffie *et al.*, 2001; Pahwa *et al.*, 2006)

5.2.3. *Estimating the burden of cancer linked to work in Canada*

Researchers from across Canada are collaborating to find out how many cancer cases and deaths are related to cancer-causing agents in Canadian workplaces, and to examine the economic impact of workplace cancers on society. This work involves calculating burden estimates for 44 workplace agents causing a total of 27 cancers, chosen based on an assessment of carcinogenicity in humans by the IARC. This study will use four sources of data:

- Epidemiological studies: the amount of risk associated with each exposure and cancer site will be selected from the published literature.
- Exposure data: exposure levels and the number of workers affected by each cancer-causing agent will be based on CAREX Canada estimates, a database of measurements taken in Canadian workplaces and other exposure data sources.
- Labour force data: the number of workers employed in each industry and occupation will be taken from the Census of Population. Labour force characteristics, such as age and tenure distribution, will be calculated using Labour Force Survey data.
- Cancer statistics: the number of newly diagnosed cancers and cancer deaths by cancer site, sex and province will be based on Canadian Cancer Registry data.

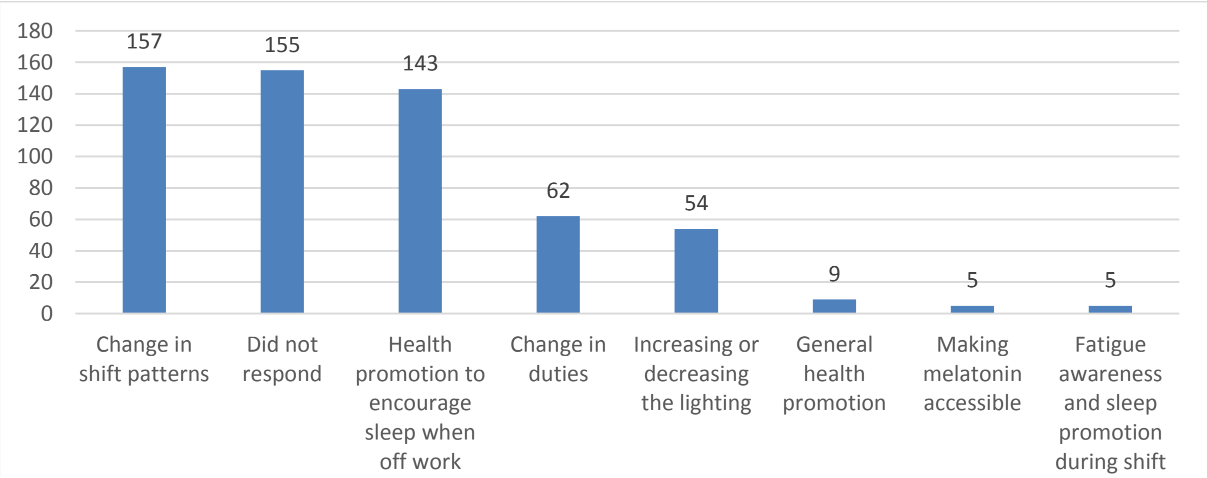
The cancers linked to occupational carcinogens will be calculated by cancer site, sex, province, industry and occupation. This research will incorporate work conducted by CAREX Canada that focuses on estimating occupational exposures in Canada, and will build on the methods of a similar study recently carried out in the UK (CCO, 2013).

5.2.4. Activities related to shift work

OCRC is undertaking a variety of activities related to shift work to assess knowledge and needs within the stakeholder community and create a venue for ongoing discussion and research. The Centre has prepared an Ontario Cancer Fact Sheet that summarises the health effects of shift work and the major industries affected.

The Centre and the Institute for Work and Health held a symposium in 2012, entitled Interventions Mitigating Health Risks of Shift Work: Current Knowledge and Workplace Practices. In preparation for this symposium, they determined stakeholder needs and current knowledge using a web-based survey about workplace practices to prevent injury and illness caused by shift work. The survey assessed knowledge of risk associated with shift work, identified types of interventions that have been proposed and/or implemented, determined who the key players involved in shift work-related interventions are and collected information on what is needed to protect the health of shift workers. Survey respondents included workers, unions, employers, researchers, and policy-makers. The survey results have been published (Pahwa *et al.*, 2012). Those who responded appear to be closely affected by shift work and are seeking to build upon their knowledge and abilities to help mitigate the health effects of shift work. Survey respondents thought that a substantial proportion of the workforce participates in shift work and that the economy is highly dependent on shift work. A major gap that emerged from this survey was between the importance of shift work and the lack of effective interventions occurring in workplaces (see Figure 8).

Figure 8: Survey on types of shift-work-related interventions. 'Have any attempts been made to change shift patterns or in other ways to reduce the health impacts of shift work in your workplace? (Check all that apply)' (n = 659)



Source: Pahwa *et al.*, 2012

5.2.5. Guidance and intervention programmes

The Sun at Work project is an example of a guidance and intervention programme. Its objective is to develop a nationally applicable, effective and sustainable sun safety programme for outdoor workers that will address both skin cancer and heat illness prevention and can be implemented by individual workplaces. It will be guided by a comprehensive knowledge translation strategy that will allow for wide distribution of the project's findings as a way of influencing policy and practice. The study received funding from the Canadian Partnership Against Cancer: Coalitions Linking Action and Science for Prevention 2 (CLASP2) competition and commenced in January 2014. (OCRC, 2014b)

5.3. Germany

5.3.1. Guidance for chemical agents

The Committee on Hazardous Substances (Ausschuss für Gefahrstoffe (AGS)) issues ‘Technical Rules on Hazardous Substances’ (TRGS) that provide guidance on how to fulfil the legal obligations. These rules have been approved by the Ministry of Labour and Social Affairs and should give clear guidance to companies. However, companies are free to use other solutions, if they can achieve the prevention and protection level required by law. Many of these technical rules deal with cancer risks (see Table 28). Some rules are also available in English and a few in French or Spanish. The rule on substitution (TRGS 600) is noteworthy: it explains in detail all necessary steps that a company has to take in order to identify a workable solution. In some cases, rules have been established on the substitution of specific substances.

TRGS 905 is a separate list of carcinogenic, mutagenic and reprotoxic substances, for which the classifications are explained in an Annex, while TRGS 906 is a list of carcinogenic activities and procedures at workplaces. There are additional explanatory statements available for the substances included. The substances/processes listed fall under German law, while factors not yet covered by legislation are not included, although scientific evidence may be available. TRGS 905 and 906 should be read in conjunction with European Directives 67/548/EWG (Dangerous Substances), now replaced by CLP, and 2004/37/EG (Carcinogens): TRGS 905 includes only substances that have a classification beyond the one contained in the European directives, they are explained in short criteria documents for each substance.

- **OELs**

The Federal Committee on Hazardous Substances and the Ministry of Labour and Social Affairs discuss (and generally approve) proposals by the German Research Foundation (DFG) Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (MAK Commission) on establishing or reviewing OELs. The OELs are called AGW (*Arbeitsplatzgrenzwert*) for air concentrations and BGW (*Biologischer Grenzwert*) for concentrations of substances in the human body. TRGS 900 contains the limits of air concentrations, TRGS 903 the biological limit values.

In cases where no threshold values can be identified, the Committee introduces risk- (or health-) based values, which are included in TRGS 900, including a substance-independent tiered control scheme that defines three exposure control bands. However, rather than defining safe or achievable levels, the aim of the concept is rather to stimulate minimisation measures in companies (Wriedt, 2012; Bender, 2012). The Committee on Hazardous Substances prepares exposure-risk relationship documentations, which are available in English for several substances (acrylonitrile, aluminium silicate fibres, asbestos, benzo[a]pyrene, 1,3-butadiene, ethylene oxide, 4,4'-methylenedianiline, and trichloroethylene). The concept is explained in TRGS 910, *Risk-related concept of measures for activities involving carcinogenic hazardous substances.*

Table 28: German technical rules (TRGS) with relevance to carcinogenic substances

TRGS Nr.	Title	Available in EN
Putting substances on the market		
TRGS 200 TRGS 201	How to classify and label substance mixtures How to classify and label substances produced in the company	

TRGS Nr.	Title	Available in EN
Risk assessment		
TRGS 400	Risk assessment for activities involving hazardous substances	EN
TRGS 420	Process-specific and substance-specific criteria (Verfahrens- und stoffspezifische Kriterien (VSK)) (soldering, sterilisation with formaldehyde, solvents in the screen printing sector)	
Preventive measures		
TRGS 513	Steriliser activities involving ethylene oxide and formaldehyde	
TRGS 521	Demolition, reconstruction and maintenance work with biopersistent mineral wools	EN
TRGS 522	Disinfection of premises using formaldehyde	
TRGS 523	Pest control using highly toxic, toxic and health hazardous substances and preparations	EN
TRGS 525	Handling of hazardous substances in medical institutions including measures to reduce risks of CMRs	
TRGS 528	Welding work	EN
TRGS 530	Hairdressers	
TRGS 551	Tar and other products generated by pyrolytic processes	
TRGS 552	N-nitrosamines	
TRGS 553	Wood dust (Holzstaub)	
TRGS 554	Diesel engine emissions	
TRGS 557	Dioxins	
TRGS 558	Activities involving high-temperature wool	EN
TRGS 559	Mineral dust	EN
Substitution		
TRGS 600	Substitution (general procedure)	EN
TRGS 611	Restrictions on the use of water-miscible or water-mixed cooling lubricants whose use can result in the formation of N-nitrosamines	EN
TRGS 615	Restrictions on the use of anticorrosion agents whose use can lead to the formation of N-nitrosamines	EN
TRGS 614	Restrictions on the use of azo dyes that can decompose into carcinogenic aromatic amines	EN

TRGS Nr.	Title	Available in EN
TRGS 619	Substitute materials for aluminium silicate wool products	EN
Occupational exposure limits		
TRGS 900	OELs (air concentration)	
TRGS 903	Biological limit values	
TRGS 905	List of carcinogenic, mutagenic or reprotoxic substances	
TRGS 906	List of carcinogenic activities or processes according to § 3 (2) no. 3 Ordinance on Hazardous Materials	
TRGS 910	Risk-related concept of measures for activities involving carcinogenic hazardous substances	EN

Source: Compiled by the authors, selected from the complete list of TRGS (BAuA 2014a)

5.3.2. Guidance for biological agents

Tatooist

In a similar way limit values are set for biological agents by the Committee on Biological Agents (ABAS). Some of these "Technical rules on biological agents" TRBA cover work with possible exposure to carcinogenic substances (Table 29): German technical rules for biological agents (TRBA) with relevance to carcinogenic substances

Technical rules on biological agents (TRBA)		
TRBA 100	Protective measures for activities involving biological agents in laboratories	EN
TRBA 220	Safety and health for activities involving biological agents in sewage plants	EN
TRBA 230	Protective measures for activities involving biological agents in agriculture and forestry and comparable activities	EN
TRBA 240	Protective measures for activities involving microbially contaminated archival materials	EN
TRBA 250	Biological agents in health-care and welfare facilities	EN
TRBA 400	Guideline for risk assessment and for the instruction of employees in relation to activities with biological agents	
TRBA 500	Basic measures to be taken for activities involving biological agents	EN

Source: Compiled by the authors, selected from the complete list of TRBA (BAuA, 2012a)

5.3.3. Other information

Accident insurance associations publish information booklets, which are often freely available on the internet. For example:

'Working safely in laboratories' (DGUV-Information 213-851 (previously BGI 850-0))
'Safety in University Chemistry Courses - An Introduction for Students' (GUV-I 8553 E)
Hazardous Substances at Universities - Information for Students and scientific employees (BG/GUV-SI 8092).
Information on hazardous substances in hospitals and care facilities' (BGI/GUV-I 8596, 'Information Gefahrstoffe im Krankenhaus – Pflege- und Funktionsbereiche')

Other booklets present specific preventive measures for certain sectors to ensure that OELs can be observed. These publications are presented on a website run by the publishing house Universum Verlag GmbH (Branchenregelungen Gefahrstoffe). A new publication has been issued on electroplating technology (BGI/GUV-I 790-016), covering Chromium VI and acids.

The Federal Institute for Occupational Safety and Health (BAuA) publishes research results and guidelines on preventive measures (for example in relation to optical radiation and to mycotoxins) on its website (BAuA, 2007).

6. Further activities of the European Agency for Safety and Health at Work

In 2012, EU-OSHA organised a workshop in Berlin, which was attended by experts from all relevant fields. The workshop drew conclusions and developed a related action plan. The following main measures were identified (EU-OSHA, 2012)

- EU-OSHA is to build (a) platform(s) to bring experts and knowledge together.
- A clear definition of the scope and resources required to underpin a case for an updated CAREX (CAREX-2) is needed.
- EU-OSHA is to support exchange of existing information regarding exposure data available at national level (the proportion of those exposed, the duration and intensity of exposures, national cancer registers, disease registers and cancers reported under compensation and insurance schemes). This exercise should always be based on data from real workplaces.
- Enhanced cooperation at European and national level between OSH enforcement authorities and REACH authorities is needed.
- EU-OSHA is to consider building on SubsPort to collect ‘minimisation examples’ of successful measures that led to a significant reduction in exposure.
- Identify examples of action that can be taken to reduce exposure amongst ‘hidden’ groups.
- EU-OSHA is to help in sharing information about interventions that consider recent changes posing a particular challenge for labour inspections (the move from industry to services, outsourcing, short-term and temporary contracts, intensification of work). How to inspect workplaces at clients’ premises? How to follow up exposures of workers in constantly changing workplaces? How to raise awareness of exposures in the service sectors?
- It is necessary to identify the issues regarding returning to work for people with work-related cancer (such as changing duties, handling the stress of returning to a job that may have been related to cancer, and so on). Develop better evidence about effective intervention types.
- Cooperation with public health stakeholders is recommended.

In 2012, EU-OSHA commissioned a state-of-the-art report on reproductive toxicants (EU-OSHA, in press) due to be published in 2014. Although the report focuses on reprotoxic substances, agents and factors, some of its conclusions also apply to occupational cancer, as many of the reprotoxic factors have carcinogenic effects. This applies not only to chemicals but also to biological factors, physical factors (such as radiation), psychosocial factors (such as stress) and organisational factors (such as shift work). Similarly, EDCs, which are of particular concern because of their reprotoxic effects, may also be responsible for the increase in cancers such as breast, endometrial, ovarian, testicular, prostate, and thyroid. As noted above, these cancers have been increasing over the past 40–50 years. (WHO, 2012)

The authors also note that the inclusion of reprotoxicants in the Carcinogens Directive should be considered, in order to have them included in national worker protection legislation and to force companies to take action in relation to such factors, with the emphasis on substitution. However, the focus should be on comprehensive risk assessment that covers both sexes, vulnerable groups (for example young workers), all developmental stages, long-term effects and all risk factors (including physical, biological and psychosocial factors), as well as combinations thereof. Factors toxic to reproduction should be given greater consideration, because of the health effects on workers and the effects on future generations. More awareness is needed. Because of the many uncertainties involved, a precautionary approach to reprotoxic factors is required, as is proper workplace risk management

7. Discussion

7.1. Benefits and limitations of exposure information systems

The exposure information from different countries presented in this report cannot be regarded as an exhaustive overview of the most important exposures; rather, it represents the exposures where more information is available and that were selected for assessment by experts. 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 1990–3) (Kauppinen *et al.*, 2000). According to the CAREX data, exposure to carcinogens at work is common and the number of workers estimated to be exposed in the early 1990s exceeded 30 million, over 20% of the entire workforce. The most common exposures among those considered were natural UVR (sunlight in regular outdoor work) and ETS (in restaurants and other workplaces) and their contribution was about half of all exposures. Since the early 1990s, exposure to ETS at work has been substantially reduced as a result of legislative measures such as prohibitions and other restrictions. Other relatively commonly occurring exposures which are likely to have decreased for similar reasons include lead, ethylene dibromide (an additive of leaded petrol), asbestos and benzene.

National registers monitoring exposures to carcinogens exist in some countries. They do not cover 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 help identify those workplaces where carcinogens are being used, and to some extent they encourage preventive measures to be taken. There is suggestive evidence that registration increases awareness and promotes preventive measures in the enterprises that have to notify exposed workers to the authorities, as has been demonstrated in Finland with regard to the ASA register (see Section 2.2.1) (Kauppinen *et al.*, 2007). Registers may also help the labour safety authorities to target their inspection, guidance and control activities. There is a risk, however, that providing notifications to the authorities becomes only an annual routine that does not result in any measures reducing carcinogen exposures and risks in workplaces.

It is important to consider that many of the chemical carcinogens identified in the measurement databases or in the estimates, including those to which workers are most frequently exposed, are generated at work and will not be tackled by the REACH legislation. Examples include diesel exhaust, welding fumes, ETS, silica, wood dust and endotoxins.

However, for those pure carcinogenic substances which do fall under REACH legislation (either registered or included in the SVHC list), the REACH processes may be very helpful in enhancing prevention of occupational cancers: use conditions and preventive measures should be determined in the exposure scenarios of the extended SDSs. The communication channels along the supply chain should be 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 may provide a better solution.

The information on the safe use of carcinogens should also be forwarded to downstream users, which in turn may promote and improve prevention. Communication of relevant information on potential health effects and how to protect oneself by those who hold the information, the producers of chemicals and mixtures, to their clients, and up and down the supply chain, is particularly important for effective prevention.

7.1.1. Validation of CAREX data

The estimates generated by CAREX and other similar information systems have not been validated using other study methods. In fact, full validation is not even feasible because of the very large number of estimates and the lack of reliable alternative data. Checking of the most relevant estimates (for example estimates indicating high exposure and those for major industries or occupations) would probably increase the validity of results. However, 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 would be available, its representativeness and applicability to the occupations or industries being assessed obviously requires expert judgement and that introduces a subjective element into the estimates.

For example, a re-evaluation of CAREX figures used in the United Kingdom study by Cherrie *et al.* using another approach (other datasets and different experts) suggested that the original estimates were mainly on the high side, although in some cases underestimation was also possible (Cherrie, van Tongeren & Semple, 2007).

Comparisons with empirical or measurement data are laborious and complex. 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 some of the disagreements may be 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.

In addition, 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. Since the actual (true) exposures are unknown, the 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.

However, the validity of exposure estimates is likely to increase in the future when more measurement data from different sources becomes available in electronic format, and the so-called 'Bayesian methods', combining measurement data and expert judgements (prior views of experts), become more widely used.

7.1.2. Sensitivity to vulnerable groups

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.

Information systems such as CAREX would be more useful for hazard surveillance, quantitative risk and burden assessment, and setting 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 (trends information), 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 related exposure information systems, such as WOODEX, TICAREX, Matgéné, FINJEM and CAREX Canada.

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) is will show data by carcinogen, region, industry, occupation, gender and level of exposure.

Exposure measurement databases include valuable information on jobs and tasks where exposure may be high. Information systems that include the level of exposure are partially able to identify the groups requiring special attention. Worker groups who are highly exposed to carcinogens may be considered as a vulnerable group in themselves and should be considered priority groups for prevention. Sharing of information on high exposures is still limited, because the data of many measurement databases is not publicly available, for confidentiality reasons. Data in these databases is potentially useful for prevention and better reporting of high-exposure situations, and dissemination of information on them would be desirable. 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. An enterprise where a high exposure has been identified may take direct action to reduce exposure, and information on this could be very valuable for similar workplaces and for labour inspectors operating in the same sector.

Exposure information systems frequently tend to underreport occasional exposures or lower exposures. This is especially relevant to young workers, who, while being vulnerable to carcinogenic substances, frequently work in temporary jobs, and, as demonstrated by the French SUMER survey, in maintenance activities and low-qualified jobs. Their exposure may go unreported because their transition into work is frequently through short-term jobs or in subcontracted activities. The chemical substances they are exposed to may also have other effects (for example endocrine disruptors that may influence their organism while it is still under development).

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.

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. Furthermore, some exposures, such as formaldehyde, cytostatic drugs, biocides and hair dyes, are not considered, or there is much less data available on them. 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.

Women workers in waste sorting

Exposures to biological agents in the food processing industry or in waste management and recycling may severely affect female workers, but there is very little information available on exposure 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. What are still not considered are the differences in metabolisation in the female organism, as most studies on health effects are based on male workers (EU-OSHA, 2013e).

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.

Welder in a steel mill

Another poorly studied issue is the effect of new forms of work on exposures to carcinogens, as well as on exposures overall. As careers become more fragmented and variable, work is done in many locations and at irregular times, and exposure patterns change. This is likely to influence both the prevalence and levels of exposure to carcinogens.

Other emerging issues which 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 or 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.

8. Conclusions and recommendations

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-raising campaigns are needed, preferably as tripartite initiatives. Awareness is probably greatest with regard to chemicals and radiation. It is considered to be very low for physical and biological factors. The pattern and variety of recognised occupational diseases linked to exposure to chemicals varies greatly across Member States. Only a very limited number of chemicals or mixtures are recognised as causative factors in the relevant lists, making it very difficult for workers to claim compensation. In many cases, there is considerable evidence of increased risks associated with particular industries and occupations. Often no specific agents can be identified as aetiological factors, making it additionally complicated to translate knowledge into worker protection legislation or classification of chemicals, because legislation as it stands often requires clearly defined factors and proof of causal relationships between factors and cancer symptoms.

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. New and emerging risks also include nanomaterials (such as carbon nanotubes), EDCs, non-ionising radiation and stress.

Occupational exposure is rarely associated with one single factor; frequently, it is a combination of risk factors, for example when shift-working cleaners in a hospital use hydrocarbons while cleaning near machines that emit electromagnetic radiation. Such mixed exposures warrant greater attention.

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 expected to improve because of REACH, which is expected to generate a large amount of toxicological data, although the challenge of mixed exposures and the difficulties of assessing mixtures for their health effects and chemicals for their interaction with other risk factors in the workplace will remain. However, the problem of process-generated substances is not tackled by REACH. This is illustrated by the long list of industries, processes and occupations that can cause cancer. This aspect is further complicated by the fast pace of change in industries, processes and employment patterns.

Back-to-work strategies needed for those affected by cancer

Issues relevant for people in recovery from work-related cancer when returning to work must be identified and addressed; for example work may need to be adapted by changing duties, the worker may need help to handle the stress of returning to a job that may have been related to their cancer, and so on. Returning to work without being exposed to the same cancer-causing factor may be difficult, for example in the case of nurses working shifts and /or nights. Clarification is needed that these workers have a right not to be exposed without being made redundant. Better evidence about effective types of intervention needs to be sought, for example by comparing non-occupational interventions with workplace interventions. Public health stakeholders should play a bigger role than at present. Cooperation with those who treat patients should also be enhanced.

Strategies need to target both women and men, and include workers in temporary and part-time jobs. An ageing working population will also have a higher proportion of chronic diseases, and strategies need to be developed to maintain working capacity and ensure decent working conditions for all.

Improvement of existing exposure assessment schemes

- Not all EU countries have followed the ILO recommendation to establish compulsory notification of workers' exposure to carcinogens. Among the EU Member States, only a few have implemented the relevant provision of the Carcinogens Directive, and even in those that have implemented it the exposure registers cover only a small proportion of the workers potentially exposed. The numbers of workers reported as exposed in the national registers (ASA, SIREP) are far smaller than the numbers in exposure information systems where the estimates are based on expert judgements, which in turn may have been based on measurements or surveys (see Section 2.2.3). The main reasons for this are that national registers cover only selected carcinogens and that there is usually substantial underreporting in data collection systems that are based on notifications made by enterprises. **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.
- Many process-generated substances, such as hardwood dust, chromium, nitrates, PAHs and asbestos, are covered by the registers. Two important cancer-causing substances that are also process-generated are quartz dust and diesel engine exhaust fumes and gas, but these are not yet covered by registers, mainly because of their very wide use range. For these substances, ways have to be found to assess exposures and identify the workplaces where workers are exposed in order to introduce better prevention and raise awareness.

Diesel truck in a dairy company

- 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, estimating 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
    - include all EU countries and all relevant carcinogenic exposures (and possibly other chemical agents of high concern)
    - incorporate trend information on exposures, if feasible
    - create a clear definition of scope and resources.

Better integration between REACH and OSH legislation

- **Many of the chemical carcinogens** identified in the measurement databases or in the estimates, including those to which workers are most frequently exposed, **are generated at work** and will not be tackled by the REACH legislation. These include, **for example, diesel exhaust, welding fumes, ETS, silica, wood dust and endotoxins**. For these very important carcinogens**, other ways of promoting prevention and raising awareness than those provided by the use of SDSs and communication up and down the supply chain through the REACH processes have to be sought, to enhance workplace protection**.
- The **positive effect of REACH and CLP could be further enhanced by better integration with OSH legislation**, for example by giving **access to data generated by REACH and CLP (self-classification)** to those who protect workers, through improved awareness and by improving information exchange on exposure situations between REACH actors and OSH stakeholders, and through **cooperation of OSH and REACH authorities at all levels**. The relationship between OSH and REACH legislation needs to be clarified in this respect.
- SDSs are one of the main information sources for workplaces. However, **advice provided through SDSs and exposure scenarios should be realistic, taking account of the special provisions of the hierarchy of control measures and the specific provisions of the Carcinogens Directive.** OSH and REACH legislation and their practical implementation need to be better articulated in this respect.
- The ILO Convention requires that exemptions from prohibitions on using carcinogenic agents may be granted only by issue of a certificate specifying in each case the conditions to be met. This requirement needs to be applied much more stringently: **for many of the key occupational carcinogens, there is a need to change attitudes to the potential risks and clearly demonstrate to employers and workers how to reduce exposures to these agents**. A clarification of REACH and OSH processes in this respect is needed.
- 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 (register from 1/1/2016), Denmark[6], Sweden and Italy. This **procedure is recommended for the whole of Europe**.

Better use of different data sources

- **Improving the contextual data of exposure measurement databases via international cooperation** would facilitate better use of exposure data in data estimations. The ongoing NECID project is an example of such cooperation. It aims to develop a nanoparticle exposure database to enable uniform storage of nanoparticle exposure data and contextual information, which will facilitate future data comparison and sharing. **Member State sources** that are difficult to understand and access for professionals from other countries because of language barriers **should be made more accessible**; examples include Poland, Slovakia and the Czech Republic, as well as France and Germany.
- **Information exchange on exposure data at national level** could also help improve assessments and identify the true proportion of those exposed, enable more information on the duration and intensity of exposure in specific jobs to be gathered and target prevention. The ongoing work to create a database and develop a model to estimate occupational exposure for a list of hazardous chemicals in the Member States of the European Union and in the European Free Trade Association (EFTA)/European Economic Area (EEA) countries (European Commission, 2013a) is expected to promote this exchange. Selected projects, such as the SYNERGY project presented in this report, promote this type of approach.

[6] the obligation to register nanomaterials with the Danish EPA's Nano Product Register only applies to nanomaterials in mixtures and articles that are intended for sale to the general public (more information can be found on the Nano Product Register's webpage: http://eng.mst.dk/topics/chemicals/nanomaterials/). Nanomaterials for occupational use are not covered by the register.

- To help identify who is at risk, **information should also be combined with knowledge gathered from national cancer registers, disease registers, and cancer reports 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.**
- 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. Exposure assessment needs to consider wider issues, such as frequent changes in workplaces and different forms of contracting work, including subcontracting and multiple, part-time or temporary contracts, and their impact on exposure patterns and levels of exposure. **Compulsory recording or reporting of even occasional exposures would help in arriving at a true assessment of exposures to cancer risk factors.** 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.
- Sources such as the cancer registries and exposure databases described can be helpful in tracking multiple exposures and identifying possible links and synergetic or multiplicative effects between risk factors. By using such tools, situations can be identified where awareness of risk is low but the number of workers exposed is potentially increasing, for example static/sedentary work.
- With increasing fragmentation, there is a risk that the link between exposure and onset of diseases may be more difficult to establish, not only for the individual worker but also at the collective level. **Information on the exposure of a worker should ideally be combined with information from social security records on the different jobs held, to make it possible for workers and those involved in monitoring health effects to draw up a plausible exposure history**.
- **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 GISCOP in France, the MEGA reports for REACH, and the Italian OCCAM project.
- OCCAM also contributes to the active search for victims of work-related cancer. Incident cases of lung, larynx and bladder cancer and leukaemia are identified from hospital records and the occupational history of the patient is automatically screened through social security records. Cases where the patient has a history of working in high-risk industries are notified to the occupational health services by Local Health Units, which identify suspected cases of occupational cancer on the basis of face-to-face interviews with patients and patients' work histories. These cases are notified to the Insurance Board for possible compensation. Such an approach could also be applied in other countries with cancer registries.

- **It is important to include part-time workers and women with a varied work history in research on work-related cancer**. Studies, such as GISCOP, which combine information from surveys, measurements and in-depth assessments of exposures (for example through interviews with workers) may help to guide this research and provide input to JEMs.
- **Full use should be made of the comprehensive data from NOCCA to analyse cancer risks by occupation and by occupational exposure.** There are many interesting findings from NOCCA that warrant further attention, and the causes of some of the identified cancers still need to be elucidated, for example of cancers of the tongue and vagina among female chemical process workers; melanoma and non-melanoma skin cancer among printers; breast cancer (in both men and women) and ovarian cancer; fallopian tube cancer among packers and hairdressers; penis cancer among drivers; and thyroid cancer among female farmers.

- Predictions on the future burden of occupational cancers are recommended, as are assessments of exposure trends. 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 future impact of present exposure.** This 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 JEMs. Examples are the burden assessments carried out in the UK and the Finnish exposure trend analyses.

Better prevention and control measures in the workplace

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 certificates specifying protection measures for each case and safeguarding medical supervision. This still remains a big challenge in terms of the wide scope of risk factors, as outlined in this report.

An important evaluation study of European strategy on safety and health, on behalf of DG EMPL, recommends a new strategy including a focus on occupational cancer deaths. It should particularly target the challenges related to the implementation of the legal framework, with an explicit focus on SMEs and micro-enterprises. The authors point out the need, in relation to many of the key occupational carcinogens, 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. The trade unions are concerned that the new strategy could represent a move away from legal regulation towards ‘soft laws’, which could undermine the existing regulatory framework for OSH. The new EU Strategic Framework on Health and Safety at Work 2014-2020 (European Commission, 2014) puts emphasis on the prevention of work-related diseases, the cost of occupational cancer to workers, companies and social security systems, and highlights the importance of anticipating emerging risks at work, changes to work organisation and the potential negative effects of new technologies on workers’ health and safety.

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 latter, Denmark has set an interesting example for lowering the barrier to compensation by more or less taking over directly all factors recognised by the IARC as cancer risk factors into national regulations.

Problems resulting from trends at the macro level must be analysed and addressed. Such trends include the move from industry to services (leading to an increase in sedentary work and a significant change in exposure patterns), outsourcing (which makes inspection of workplaces a challenging task), short-term and temporary contracts (a major issue for medical supervision) and the intensification of work (which makes stress a notable factor that may contribute to risk levels). The research results need to be translated into workplace measures that will protect workers from the effects of these changes, an adaptation of inspections and the provision of preventive services to ensure coverage of these workers. Vulnerable and ‘hidden’ groups must be identified and strategies to reduce exposures for them must be developed.

The following recommendations are based on some of the successful approaches identified in this report:

- 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.
- The specific issue of shift work/night work and cancer is not yet specifically addressed in European legislation and guidance. However, the legislative framework and, more specifically, the directives on working time apply, and preventive measures can be set following risk assessment. There are some examples of guidance available, for example the guidance from Canada presented in this report, and studies from the UK have attempted to assess the impact of implementation of different measures on cancer figures.
- Exposure to environmental tobacco smoke has been considerably reduced by the introduction of smoking bans. However, **in some areas (services provided in private homes, hospitality sector with mixed smoking and non-smoking areas, police and prisons, emergency services, outdoor workers), workers are less protected**. **Prevention measures should be sought for these workers to ensure equal protection, awareness-raising measures are also needed and should include clients of these services. Risk assessment tools such as the one designed by Health Services Executive in Ireland can be helpful in that respect.**
- **Awareness-raising and prevention strategies are needed, especially for the service sector**, where 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.
- Following the ILO convention and recommendation, exposure to carcinogenic factors during work is generally prohibited, but exceptions may be granted under very strict conditions, including the issuing of a certificate specifying in each case the protection measures to be applied. Ideally, these specifications should be sector-occupation-specific, covering all conditions and factors, including chemicals, biological agents and physical and organisational factors. The measures should also consider the precautionary principle when sufficient data are not yet available. In order to allow continuous updating, the guidance should be web-based and interactive.
- Specifications are available in some Member States, for example, in the case of chemical factors, the German TRGS, but the situation is far from satisfactory, and the ILO requirements should be fully implemented. The guidelines for companies, labour inspections and accident/health insurance organisations should preferably be interactive comprehensive risk assessment tools that cover all types of risks. **Standard risks assessments**, such as the process- and substance-specific criteria published by the German AGS **could serve as an example.**
- Projects are needed to **identify worker groups at high risk of contracting occupational cancer; 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.
- Experience from France shows that inspected companies understood the risks much better and were more motivated to take action. This may lead us to conclude that there should be a **higher presence of labour inspectors and more inspections, especially in small companies**. To bolster notoriously scarce resources for labour inspections, Member States could follow the Swedish example: Sweden has a very interesting and unique system of regional safety representatives for small workplaces. They are appointed by the trade unions and can inspect SMEs. The costs of the inspections are partly covered by the government.
- **In addition, preventive services play an important role in exposure assessment at workplaces and giving advice to companies**. Unfortunately, the role and tasks of preventive services are frequently not clarified and resources are becoming scarce in some of the Member States, in particular a shortage of occupational physicians.

- The Carcinogens Directive foresees notifications, record-keeping and communicating anonymised results to workers. However, Member States have often not implemented these regulations at workplace level. **The information rights of workers should also be strengthened to empower them to protect themselves and allow them to benefit from an informed consultation at workplace level.**
- It is good decision-making practice to **assess the consequences of carcinogen exposure when setting and changing OELs or other regulations**. An example of this is the SHEcan study. The goal of new approaches in Germany and the Netherlands is the continuous reduction of exposure to carcinogenic chemicals towards an acceptable level (health- or risk-based OELs). Its aim is to substantially accelerate the implementation of prevention measures. This approach should be closely monitored and evaluated.

However, limit values cannot be set for a number of factors because of various problems, as described in this report. In these cases, risk assessment, and preventive measures to be derived from it cannot rely on exposure measurement. 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.

Minimisation of risk and the precautionary principle

- **Avoidance of exposure and substitution are important prevention principles and companies need more guidance on avoiding and substituting carcinogenic agents/factors**. Portals and databases collecting successful examples and providing such information in a systematic way, such as SubsPort, should be further developed.
- 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. OSH researchers have to provide relevant guidelines in collaboration with accident insurance associations and labour inspectorates.

There is a demand for a new cancer prevention paradigm that should be based on an understanding that cancer is ultimately caused by multiple interacting factors. Such approaches need to be developed by researchers and professionals, and they should be included in the development of guidelines, tools and possibly SDSs. Such a precautionary approach also needs to consider the changes in the world of work.

OSH research and prevention should place more emphasis on the factors listed below.

- Collection and use of empirical data on exposure to carcinogens.
- Reliable information on the extent and levels of exposure is the basis for effective prevention of occupational cancer risks.
- Collection, analysis and dissemination of information on occupations and work tasks entailing high exposure. This kind of information is required to target preventive measures to workers at high risk.
- Changes in the world of work, such as an increasingly diverse working population, the growth in subcontracting, temporary work, multiple jobs, working at clients' premises with limited possibilities for adaptation, increasingly static work, the move from industry to service sectors, growth in the numbers of women in exposed occupations, atypical working times and increasing multiple exposures.
- The effects of mixed exposures.

9. References

Ahrens, A., Braun, A., von Gleich, A., Heitmann, K. & Lißner, L. *Hazardous chemicals in products and processes: Substitution and beyond*, Innovation and Sustainability Series, Physica-Verlag, Heidelberg, Berlin, 2006.

Aitken, R.A, Bassan, A., Friedrichs, S., Hankin, S.M., Hansen, S.F., Holmqvist, J., Peters, S.A.K., Poland, C.A., Tran, C.L., 'Specific Advice on Exposure Assessment and Hazard/Risk Characterisation for Nanomaterials under REACH (RIP-oN 3) – Final Project Report', 2011. Available at http://ec.europa.eu/environment/chemicals/nanotech/pdf/report_ripon3.pdf

Alavanja M.C.R., Sandler D.P., Lynch C.F., *et al.* Cancer incidence in the Agricultural Health Study.Scandinavian Journal of Work, Environment and Health;31(suppl 1), 2005, p. 39–45.

Amendola, P., Audisio, R., Scaburro, A., Ariano, E., Cavuto, S., Imbriani, M., Massari, S., Scarselli, A. & Crosignani, P., 'The active search for occupational cancer cases: Bladder cancer in Lombardy Region [in Italian]', *Epidemiol Prev* 29, 2005, pp. 253–8. Available at: http://www.occam.it/en/resources/E&P2005.pdf

Bagschik, U., Böckler, M., Chromy, W., Dahmann, D., Gabriel, S., Gese, H., Guldner, K., Fendler, D., Kolmsee, K., Kredel,P., Kraus, J., Mattenklott, M., Möller, A., Münch, J., Sonnenschein,G., Steinig, O., Tigler, A., Van Gelder, R., 'Exposure to quartz at the workplace', German Institute for Occupational Safety (the BGIA), Report 8/2006e, 2006. Available at http://www.dguv.de/medien/ifa/en/pub/rep/pdf/rep05/biar0806/rep8_2006_e.pdf.

Barford, E., 'Study raises concerns over anaesthetic's possible link to cancer recurrence', Imperial College, London, 2013. Retrieved 9 October 2014, from: http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_28-6-2013-14-41-11

BAuA – German Federal Agency for Safety at Work and Occupational Medicine, *Importance of mycotoxins in the context of the workplace risk assessment (Bedeutung von Mykotoxinen im Rahmen der arbeitsplatzbezogenen Gefährdungsbeurteilung)*, Progress report (Sachstandsbericht) [in German], 2007. Available at: http://www.baua.de/de/Themen-von-A-Z/Biologische-Arbeitsstoffe/ABAS/aus-dem-ABAS/pdf/Bedeutung-von-Mykotoxinen.pdf

BAuA – German Federal Agency for Safety at Work and Occupational Medicine (2012b), *TRBA 500 basic measures to be taken for activities involving biological agents*. Available at: http://www.baua.de/en/Topics-from-A-to-Z/Biological-Agents/TRBA/TRBA-500.html

BAuA – German Federal Agency for Safety at Work and Occupational Medicine (2014a). Technical Rules on Hazardous Substances (TRGS). Retrieved 28 October 2014, from: http://www.baua.de/en/Topics-from-A-to-Z/Hazardous-Substances/TRGS/TRGS.html

BAuA – German Federal Agency for Safety at Work and Occupational Medicine (2014b). Technical Rules on Biological Agents (TRBA). Retrieved 1 April 2014, from: http://www.baua.de/en/Topics-from-A-to-Z/Biological-Agents/TRBA/TRBA.html

Bender, H.F., *Acceptable, tolerable, non-tolerable risks at the workplace,* presentation at the EU-OSHA workshop Carcinogens and Work-Related Cancer, Berlin, 3–4 September 2012. Retrieved 4 July 2013, from: https://osha.europa.eu/en/seminars/workshop-on-carcinogens-and-work-related-cancer/speech-venues/session-1c-cancer-prevention-action-plans-and-campaigns-to-prevent-work-related-cancer/french-governmental-plans-and-national-labour-inspectorate-campaign

Blair, A., 'Occupation and cancer in the Nordic countries: Editorial', *Acta Oncol* 48, 2009, pp. 644–5. Available at: http://astra.cancer.fi/NOCCA/full-article.html

Blair, A., Marrett, L. & Freeman, L.B., 'Occupational cancer in developed countries', *Environmental Health*, 10, Supplement 1, 2011. Available at: http://www.ehjournal.net/supplements/10/S9

Blanco-Romero, L., Vega, L., Lozano-Chavarria, L. & Partanen, T., 'CAREX Nicaragua and Panama: Worker exposures to carcinogenic substances and pesticides', *Int J Occup Health* 17, 2011, pp. 251–7.

Boffetta, P., Saracci, R., Kogevinas, M., Wilbourn, J. & Vainio, H., 'Occupational carcinogens', *ILO encyclopaedia*, 2003. Available at: http://www.ilo.org/safework_bookshelf/english

Bowman, J., Touchstone, J. & Yost, M., 'A population-based job exposure matrix for power-frequency magnetic fields', *J Occup Environ Hyg* 4, 2007, pp. 715–28.

Boyle, T., Fritschi, L., Heyworth, J. & Bull, F., 'Long-term sedentary work and the risk of subsite-specific colorectal cancer', *Am J Epidemiol* 173(10), 2011, pp. 1183–91. Available at: http://www.ncbi.nlm.nih.gov/pubmed/21421743

Branchenregelungen Gefahrstoffe, Website http://www.arbeitsschutz-center.net/branchenregelungen/index.php. Brown, J.R. & Thornton, J.L., 'Percivall Pott (1714–1788) and chimney sweepers' cancer of the scrotum', *Occupational & Environmental Medicine* (previously *British Journal of Industrial Medicine*), 14(1,) 1957, pp. 68–70. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1037746/?page=1

Burns, D. & Beaumont, P., 'The HSE National Exposure Database–(NEDB)', *Ann Occup Hyg* 33, 1989, pp. 1–7.

Cairns, J., 'The possible prevention of cancer', *Environmental Health*, 10, Supplement 1, 2011. Available at: http://www.ehjournal.net/supplements/10/S1/S13

CAREX Canada (2013). CAREX Canada database. Retrieved 29 April 2014, from: http://www.carexcanada.ca/en/

CAREX Website: available at: http://www.ttl.fi/en/chemical_safety/carex/pages/default.aspx

Carey, R.N., Driscoll, T.R., Peters, S., Glass, D.C., Reid, A., Benke, G. & Fritschi, L. 'Estimated prevalence of exposure to occupational carcinogens in Australia (2011–2012)', *Occup Environ Med* 71(1), 2014, pp. 55–62.

CCO – Cancer Care Ontario (2013). 'Canadian team working to identify the most important workplace carcinogens'. Retrieved 22 April 2014, from: https://www.cancercare.on.ca/cms/one.aspx?portalId=1377&pageId=293371

CCOHS – Canadian Centre for Occupational Health and Safety (2012). 'Skin cancer and sunlight'. Retrieved 10 April 2014, from: http://www.ccohs.ca/oshanswers/diseases/skin_cancer.html#_1_2

CDC – Centers for Disease Control and Prevention, *Current Intelligence Bulletin 65: Occupational Exposure to Carbon Nanotubes and Nanofibers*, DHHS (NIOSH) Publication Number 2013-145, April 2013, NIOSH Publications and Products. Retrieved 21 September 2013, from: http://www.cdc.gov/niosh/docs/2013-145/

Certin, J.-F., Fariol, M., Héry, M., langlois, E. & Vincent, R., 'Résultats de la campagne de contrôle 2006 "Inspection du travail – prévention des risques professionnels des CRAM" (avec le soutien de l'INRS) sur l'utilisation des agents cancérogènes, mutagènes et toxiques pour la reproduction dans l'industrie', *Hygiène et sécurité du travail: Cahiers de notes documentaires* 207, 2007, p. 77–84. Available at http://www.inrs.fr/accueil/dms/inrs/CataloguePapier/ND/TI-PR-27/pr27.pdf.

Cherrie, J., *Updating the European Carcinogens Directive*, Institute of Occupational Medicine, Edinburgh, UK, presentation at the Irish Occupational Hygiene Society conference, 2013. Retrieved 4 July 2013, from: http://de.slideshare.net/JohnCherrie/updating-the-european-carcinogens-directive

Cherrie, J., van Tongeren, M. & Semple, S., 'Exposure to occupational carcinogens in Great Britain', *Ann Occup Hyg* 51, 2007, pp. 653–64.

Clapp, R.W., Jacobs, M.M. & Loechler, E.L., *Environmental and occupational causes of cancer: New evidence, 2005–2007*, Lowell Center for Sustainable Production, 2007.

COLCHIC database, http://www.portail-rrsstq.com/fiches/Colchic.html

Council of the European Union, *Recommendation of 30 November 2009 on smoke-free environments*, OJ C 296, 5.12.2009, p. 4–14. Available at http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009H1205%2801%29

Council of the European Union, *Council Directive 2013/59/EURATOM of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom*, 2014. OJ L:013, 17.01.2014. Available at: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=OJ:L:2014:013:TOC .

Counil, E. & Thébaud-Mony, A., 'The burden of work-related cancer in France', paper presented at the EU-OSHA workshop Carcinogens and Work-Related Cancer, Berlin, 3–4 September 2012. Available at: see at: https://osha.europa.eu/en/seminars/workshop-on-carcinogens-and-work-related-cancer/speech-venues/session-a-methods-to-assess-exposure-to-carcinogens-and-the-work-related-cancer-burden/the-burden-of-work-related-cancer-in-france

Creely, K., Cowie, H., van Tongeren, M., Kromhout, H., Tickner, J. & Cherrie, J., 'Trends in inhalation exposure: A review of the data in the published scientific literature', *Ann Occup Hyg* 51, 2007, pp. 665–78.

Crosignani, P., Audisio, R., Amendola, P., Scaburri, A., Contiero, P., Mirainaccio, A. & Imbriano, M.I., 'The active search for occupational cancers [in Italian]', *Epidemiol Prev* 33, Supplement 2, 2009, pp. 71–3. Available at: http://www.occam.it/en/resources/E&P2009.pdf

Crosignani, P., Marinaccio, A., Audisio, R., Amendola, P., Scaburri, A. & Imbriani, M., 'The OCCAM project: An innovative Italian approach to an old problem', *HESA Newsletter*, June 2008, pp. 24–6. Available at: http://scholar.googleusercontent.com/scholar?q=cache:YZVKIPYh2W4J:scholar.google.com/+The+OCCAM+project.+An+innovative+Italian+approach+to+an+,old+problem&hl=fi&as_sdt=0,5&as_vis=1

Czerczak S., 'Zasady ustalania wartości najwyższych dopuszczalnych stężeń chemicznych czynników szkodliwych w środowisku pracy', *Podstawy i Metody Oceny Środowiska Pracy*, 4(42), 2004, pp. 5–18.

DARES, Ministère du travail, de l'emploi, de la formation professionnelle et du dialogue social, L´enquête SUMER 1994, Accessed 28 October 2014, http://travail-emploi.gouv.fr/etudes-recherches-statistiques-de,76/statistiques,78/conditions-de-travail-et-sante,80/les-enquetes-surveillance-medicale,1999/l-enquete-sumer-1994,15983.html

DARES, Ministère du travail, de l'emploi, de la formation professionnelle et du dialogue social, L´enquête SUMER 2003. Accessed 28 October 2014, http://travail-emploi.gouv.fr/etudes-recherches-statistiques-de,76/statistiques,78/conditions-de-travail-et-sante,80/les-enquetes-surveillance-medicale,1999/l-enquete-sumer-2003,15982.html

DARES, Ministère du travail, de l'emploi, de la formation professionnelle et du dialogue social, L´enquête SUMER 2010. Accessed 28 October 2014, http://travail-emploi.gouv.fr/etudes-recherches-statistiques-de,76/statistiques,78/conditions-de-travail-et-sante,80/les-enquetes-surveillance-medicale,1999/l-enquete-sumer-2010,15981.html

DARES. Ministère de l'emploi, de la cohésion sociale et du logement, *Les expositions aux produits cancérogènes*, Premières Synthèses Informations, No 28.1, July 2005. Available at: http://www.cancer-environnement.fr/LinkClick.aspx?fileticket=0-6qVAu1pz0%3D&mid=1313&tabid=235

DARES. Ministère du travail, de l'emploi, de la formation professionnelle et du dialogue social, *Les expositions aux produits chimiques cancérogènes en 2010*, DARES Analyses No 54, September 2013. Available at: http://travail-emploi.gouv.fr/IMG/pdf/2013-054-2.pdf

DGUV – Deutsche Gesetzliche Unfallversicherung (German Social Accident Insurance Association) (no date). 'Hazardous substances information system of the German Social Accident Insurance: GESTIS DNEL Database'. Retrieved 28 April 2014, from: http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-DNEL-Datenbank/index-2.jsp

Driscoll, T., Nelson, D., Steenland, K., Leigh, J., Concha-Barrientos, M., Fingerhut, M. & Prüss-Üstün, A., 'The global burden of diseases due to occupational carcinogens', *Am J Indust Med* 48, 2005, pp. 419–31. Available at: http://onlinelibrary.wiley.com/doi/10.1002/ajim.20209/abstract

ECHA – European Chemicals Agency, Guidance on information requirements and chemical safety assessment, Chapter R.8, 'Characterisation of dose [concentration]-response for human health', Version 2.1, November 2012. Available at: http://echa.europa.eu/documents/10162/13632/information_requirements_r8_en.pdf.

ECHA – European Chemicals Agency (2013a). SVHC Roadmap to 2020. Implementation Plan. Available at http://echa.europa.eu/documents/10162/19126370/svhc_roadmap_implementation_plan_en.pdf

ECHA – European Chemicals Agency (2013b). 'Candidate List of Substances of Very High Concern for Authorisation' (published in accordance with Article 59(10) of REACH). Retrieved 11 April 2014, from: http://echa.europa.eu/web/guest/candidate-list-table

ECHA – European Chemicals Agency (2014a). Homepage. Retrieved 12 April 2011, from: http://www.echa.europa.eu

ECHA – European Chemicals Agency (2014b). C&L Inventory database. Retrieved 9 April 2014, from: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-databaseECHA – European Chemical Agency (no date). 'Substances of potential concern'. Retrieved 24 April 2014, from: http://echa.europa.eu/addressing-chemicals-of-concern/substances-of-potential-concern

ETUI – European Trade Union Institute, *Occupational cancer. The Cinderella disease.* 2007, Mengeot, M.-A., Musu, T., Vogel, L., Retrieved 29 October 2014, from http://www.etui.org/Publications2/Guides/Occupational-cancer.-The-Cinderella-disease

ETUI – European Trade Union Institute (2012). 'Carcinogens Directive revision: Major milestone passed'. Retrieved 4 July 2013, from: http://www.etui.org/Topics/Health-Safety/News/Carcinogens-Directive-revision-major-milestone-passed

ETUI – European Trade Union Institute (2014). *'Preventing work cancers. A workplace health priority'*, Mengeot, M.-A., Musu, T., Vogel, L., Retrieved 29 October 2014, from http://www.etui.org/Publications2/Guides/Preventing-work-cancers.-A-workplace-health-priority

EU-OSHA – European Agency for Safety and Health at Work, *Factsheet 34: Elimination and substitution of dangerous substances*, 2003. Available at: https://osha.europa.eu/en/publications/factsheets/34

EU-OSHA – European Agency for Safety and Health at Work, *Exploratory survey of occupational exposure limits for carcinogens, mutagens and reprotoxic substances at EU Member State levels*, Publications Office of the of the European Union, Luxembourg, 2009a. Available at: https://osha.europa.eu/en/publications/reports/548OELs

EU-OSHA – European Agency for Safety and Health at Work, *Workplace exposure to nanoparticles*, European Risk Observatory, literature review, Publications Office of the European Union, Luxembourg, 2009b. Available at: https://www.osha.europa.eu/en/publications/literature_reviews/workplace_exposure_to_nanoparticles

EU-OSHA – European Agency for Safety and Health at Work (2012). Workshop on carcinogens and work-related cancer. Retrieved 29 April 2014, from https://osha.europa.eu/en/seminars/workshop-on-carcinogens-and-work-related-cancer

EU-OSHA – European Agency for Safety and Health at Work (2013a), *E-fact 59 - Tobacco: advice for smokers on health effects*. Available at https://osha.europa.eu/en/publications/e-facts/efact-59-tobacco-advice-for-smokers-on-health-effects/view

EU-OSHA – European Agency for Safety and Health at Work (2013b), *E-fact 60 - Tobacco: advice for non-smokers on health effects*. Available at https://osha.europa.eu/en/publications/e-facts/efact60-tobacco-advice-for-non-smokers-on-health-effects/view

EU-OSHA – European Agency for Safety and Health at Work (2013c), *E-fact 61 - Tobacco: advice for employers on creating a smoke-free working environment*. Available at https://osha.europa.eu/en/publications/e-facts/efact-61-tobacco-advice-for-employers-on-creating-a-smoke-free-working-environment/view

EU-OSHA – European Agency for Safety and Health at Work (2013d), *Napo in … lungs at work*. Available at http://www.napofilm.net/en/napos-films/multimedia-film-episodes-listing-view?filmid=napo-016-lungs-at-work

EU-OSHA – European Agency for Safety and Health at Work (2013e), *New risks and trends in the safety and health of women at work.* Available at https://osha.europa.eu/en/publications/reports/new-risks-and-trends-in-the-safety-and-health-of-women-at-work/view

EU-OSHA – European Agency for Safety and Health at Work (2014), *Workplace risks affecting reproduction: From knowledge to action*, ANSES (French Agency for Food, Environmental and Occupational Health and Safety), 15–16 January 2014, proceedings. Retrieved 12 August 2014, from https://osha.europa.eu/en/seminars/workplace-risks-affecting-reproduction-from-knowledge-to-action

EU-OSHA – European Agency for Safety and Health at Work, *State of the art report on reproductive toxicants*, in press, to be published by the Publications Office of the European Union, Luxembourg.

EU-OSHA – European Agency for Safety and Health at Work (no date). Case studies (searchstring: 'Nano'). Retrieved 1 April 2014, from: https://osha.europa.eu/en/practical-solutions/case-studies?SearchableText=nano&is_search_expanded=True&getRemoteLanguage=&subcategory2=&nace2=&multilingual_thesaurus2=&submit=Search

Eurofound – European Foundation for the Improvement of Living and Working Conditions, *Third European Working Conditions Survey (2000*), final report, 2000. Available at: http://www.eurofound.europa.eu/working/surveys/previoussurveys/survey2000.htm

Eurofound – European Foundation for the Improvement of Living and Working Conditions, *Fourth European Working Conditions Survey (2005*), final report, 2005. Available at: http://eurofound.europa.eu/surveys/ewcs/2005/european-working-conditions-survey-2005

Eurofound – European Foundation for the Improvement of Living and Working Conditions, *Fifth European Working Conditions Survey (2010*), final report, 2010 Available at: http://www.eurofound.europa.eu/surveys/ewcs/2010/

Eurofound - EWCS 2005, http://www.eurofound.europa.eu/surveys/ewcs/2005/index.htm

Eurofound - EWCS 2010, http://www.eurofound.europa.eu/surveys/ewcs/2010/

European Commission, *Council Directive of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work (89/391/EEC)*, consolidated version as per March 2008, OJ L 391. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:01989L0391-20081211:EN:NOT

European Commission, Commission Recommendation 2003/670/EC of 19 September 2003 concerning the European schedule of occupational diseases, O J L 238 , 25/09/2003. Available at http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32003H0670

European Commission, *Directive 2004/37/EC of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (Sixth individual Directive within the meaning of Article 16(1) Directive 89/391/EEC)*, OJ L 158, 30.4.2004. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32004L0037R%2801%29:EN:NOT

European Commission - Directorate-General for Employment, Social Affairs and Inclusion, *Practical guidelines of a non-binding nature on the protection of the health and safety of workers from the risks related to chemical agents at work*, Luxembourg: Publications Office of the European Union, 2006. Available at: http://bookshop.europa.eu/is-bin/INTERSHOP.enfinity/WFS/EU-Bookshop-Site/en_GB/-/EUR/ViewPublication-Start?PublicationKey=KE6805058

European Commission, *Communication from the Commission to the European Parliament, the Council and the European Economic and Social Committee*, *Regulatory aspects of nanomaterials*, Brussels, Commission of the European Communities, 2008b. Available at: http://ec.europa.eu/nanotechnology/pdf/comm_2008_0366_en.pdf

European Commission, *Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 (Text with EEA relevance)*, OJ L 353, 2008a. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008R1272:EN:HTML

European Commission, Consultation (Article 138) of the European social partners on the protection of workers from risks related to exposure to environmental tobacco smoke at the workplace, 2008c. Available at http://ec.europa.eu/social/BlobServlet?docId=1933&langId=en

European Commission, *Information notices on occupational diseases: a guide to diagnosis*, 2009a. Available at ec.europa.eu/social/BlobServlet?docId=3155&langId=en

European Commission, *Survey on tobacco. Analytical report*. Flash Eurobarometer nr. 253, 2009b. Available at http://ec.europa.eu/public_opinion/flash/fl_253_en.pdf

European Commission, Directorate-General for Employment, Social Affairs and Inclusion, CADimple report, Contract to analyse and evaluate the impact of the practical implementation in the workplace of national measures implementing Directive 98/24/EC on Chemical Agents, final report, 2010. Available at: http://ec.europa.eu/social/BlobServlet?docId=10152&langId=en

European Commission, *Occupational health and safety risks in the health care sector: Guide to prevention and good practice*, Publications Office of the European Union, Luxembourg, 2011. Available at: http://ec.europa.eu/social/BlobServlet?docId=7167&langId=en.

European Commission – Directorate-General for Employment, Social Affairs and Inclusion, *Minimising chemical risk to workers' health and safety through substitution*, Publications Office of the European Union, Luxembourg, 2012. Available at: http://bookshop.europa.eu/en/minimising-chemical-risk-to-workers-health-and-safety-through-substitution-pbKE3012758/?CatalogCategoryID=Ke4KABstjN4AAAEj8pAY4e5L

European Commission, *Service contract to create a database and develop a model to estimate the occupational exposure for a list of hazardous chemicals in the Member States of the European Union and in the EFTA/EEA countries, Tender specifications – Call for tender n° VT/2013/079 – Technical part*, Ref. Ares(2013)3108597, 25 September 2013 (2013a). Available at: http://ec.europa.eu/social/BlobServlet?docId=10975&langId=en

European Commission, Directorate-General for Employment, Social Affairs and Inclusion, *Evaluation of the European Strategy on Safety and Health at Work 2007–2012*, final report prepared by Milieu, IOM and COWI, 2013b. Available at: ec.europa.eu/social/BlobServlet?docId=10016&langId=en

European Commission, *Roadmap for SVHCs identification and implementation of REACH Risk Management measures from now to 2020*, 2013c. Available at http://register.consilium.europa.eu/doc/srv?l=EN&f=ST%205867%202013%20INIT.

European Commission, *Report on the current situation in relation to occupational diseases' systems in EU Member States and EFTA/EEA countries, in particular relative to Commission Recommendation 2003/670/EC concerning the European Schedule of Occupational Diseases and gathering of data on relevant related aspect*, 2013d. Available at: http://ec.europa.eu/social/BlobServlet?docId=9982&langId=en

European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on an EU Strategic Framework on Health and Safety at Work 2014-2020, from 6 June 2014, COM(2014) 332 final. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0332.

European Commission, Commission Staff Working Document *Report on the implementation of the Council Recommendation of 30 November 2009 on Smoke-free Environments* (2009/C 296/02),

European Parliament and Council of the European Union, *Directive 2006/25/EC of 5 April 2006 on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation) (19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EC)*, OJ L 114, 27 April 2006, pp. 38–59. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:114:0038:0059:EN:PDF

Fernández, E., Fu, M., Pascual, J.A., López, M.J., Pérez-Ríos, M., Schiaffino, A., Martínez-Sánchez, J.M., Ariza, C., Saltó, E., Nebot, M., Spanish Smoking Law Evaluation Group. 'Impact of the Spanish smoking law on exposure to second-hand smoke and respiratory health in hospitality workers: a cohort study', *PLoS One* 4(1), 2009, e4244. Available at http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0004244.

Févotte, J., Dananché, B., Delabre, L., Ducamp, S., Garras, L., Houot, M., Luce, D., Orlowski, E., Pilorget, C., Lacourt, A., Brochard, P., Goldberg, M. & Imbernon, E,. 'Matgéné: a program to develop job-exposure matrices in the general population in France', *Ann Occup Hyg* 55(8), 2011, pp. 865–78.

Févotte, J., Luce, D., Arslan, M., Dananché, B., Delabre, L., Ducamp, S., Garras, L., Orlowski, E., Pilorget, C., Thuret, A., Goldberg, M. & Imbernon, E., 'Surveillance des expositions d'origine professionelle en population générale: Le programme Matgéné', *Bull Epidemiol Hebd* 46–7, 2006, pp. 362–5. Available at: http://opac.invs.sante.fr/index.php?lvl=notice_display&id=4386

FIOH – Finnish Institute of Occupational Health (2013a). CAREX – International Information System on Occupational Exposure to Carcinogens. Retrieved 29 April 2014, from: http://www.ttl.fi/en/chemical_safety/carex/pages/default.aspx (restricted access database).

FIOH – Finnish Institute of Occupational Health (2013b). The Finnish national job-exposure matrix (FINJEM). (The use of the matrix is coordinated by FIOH; see http://www.ttl.fi/fi/rekisterit/finjem/Sivut/default.aspx)

Fox, B.H., 'Cancer', *ILO encyclopaedia*, 2003. Available at: http://www.ilo.org/safework_bookshelf/english

Franco, G. & Franco, F., 'Bernardino Ramazzini: The Father of Occupational Medicine', *American Journal of Public Health,* 91(9), 2001, p. 1382. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1446786/

Gabriel, S., 'The BG Measurement System for Hazardous Substances (BGMG) and the Exposure Database of Hazardous Substances (MEGA)', *Int J Occup Saf Ergon* 12(1), 2006, pp. 101–4. Available at: http://www.ncbi.nlm.nih.gov/pubmed/16554004

Gabriel, S., Koppisch, D. & Range, D., 'The MGU: A monitoring system for the collection and documentation of valid workplace exposure data', *Gefahrstoffe: Reinhaltung der Luft* 70(1–2), 2010, pp. 43–9.

Garcia, A., Gonzales-Galarzo, M., Kauppinen, T., Delclos, J. & Benavides, F., 'A job-exposure matrix for research and surveillance of occupational health and safety in Spanish workers: MatEmESp', *Am J Ind Med* 56, 2013, pp. 1226–38.

GISCOP Website, http://www.univ-paris13.fr/giscop/

Gorini G., ' Impact of the Italian smoking ban and comparison with the evaluation of the Scottish ban', *Epidemiol Prev*. 35(3-4 Suppl 1), 2011, p. 4-18.

Greenwald, P. & Warshaw, L.J., 'Cancer prevention and control', *ILO encyclopaedia*, 2003. Available at: http://www.ilo.org/safework_bookshelf/english

Grosse, Y., Loomis, D., , Guyton, K.Z., Lauby-Secretan, B., El Ghissassi, F., Bouvard, V., Benbrahim-Tallaa, L., Guha, N., Scoccianti, C., Mattock, H., Straif, K., 'Carcinogenicity of fluoro-edenite, silicon carbide fibres and whiskers, and carbon nanotubes', *The Lancet Oncology*, Early Online Publication, 31 October 2014. Available at http://www.thelancet.com/journals/lanonc/article/PIIS1470-2045%2814%2971109-X/fulltext?_eventId=login

Hankin S.M., Peters S.A.K., Poland C.A., Foss Hansen S., Holmqvist J., Ross B.L., 'Specific advice on fulfilling information requirements for nanomaterials under REACH (RIP-oN 2) – Final Project Report', 2011. Available at http://ec.europa.eu/environment/chemicals/nanotech/pdf/report_ripon2.pdf

Health and Safety Executive – HSE, 2012, *The burden of occupational cancer in Great Britain. Melanoma,* Health and safety Research report 860. Available at http://www.hse.gov.uk/research/rrpdf/rr800.pdf

Health Service Executive, *Risk assessment guidance tool for environmental tobacco smoke*, 2009. http://www.hse.ie/eng/services/publications/Mentalhealth/Risk_assessment_guidance_tool_for_Environmental_Tobacco_Smoke_.pdf

Heederik, D., *Endotoxins: An emerging biological risk?*, presentation at the EU-OSHA workshop Occupational Risks from Biological Agents: Facing up to the Challenges, Brussels, 6–7 June 2007. Retrieved 31 March 2014, from: https://osha.europa.eu/en/seminars/occupational-risks-from-biological-agents-facing-up-the-challenges/speech-venues/speeches/endotoxins-an-emerging-biological-risk

van der Heijden, C.A., 'Carcinogen risk assessment', *ILO encyclopaedia*, 2003. Available at: http://www.ilo.org/safework_bookshelf/english

HSE – Health and Safety Executive (UK) (no date). Activities. Retrieved 28 April 2014, from: http://www.hse.gov.uk/cancer/activities.htm

Hutchings, S., Cherrie, J.W., van Tongeren, M. & Rushton, L., 'Intervening to reduce the future burden of occupational cancer in Britain: What could work?', *Cancer Prevention Research,* 5(10), 2012, pp. 1213–22.

Hutchings, S. & Rushton, L., *The burden of occupational cancer in Great Britain: Predicting the future burden of occupational cancer – Methodology*, Imperial College London, prepared for the Health and Safety Executive (UK), 2011. Available at: http://www.hse.gov.uk/research/rrpdf/rr849.pdf

Hutchings, S. & Rushton, L., 'Occupational cancer in Britain: Statistical methodology', *Br J Cancer* 107, 2012, pp. S8-S17.

IARC - International Agency for Research on Cancer, Painting, Firefighting, and Shiftwork, IARC Monographs Volume 98, Lyon, 2010. Available at: http://monographs.iarc.fr/ENG/Monographs/vol98/index.php

IARC – International Agency for Research on Cancer, *Biological agents*, IARC Monographs Volume 100B, Lyon 2012a. Available at http://monographs.iarc.fr/ENG/Monographs/vol100B/index.php

IARC – International Agency for Research on Cancer, *Radiation*, IARC Monographs Volume 100 D, Lyon, 2012b. Available at: http://monographs.iarc.fr/ENG/Monographs/vol100D/mono100D.pdf

IARC – International Agency for Research on Cancer (2013). 'IARC monographs on the evaluation of carcinogenic risks to humans'. Retrieved 26 June 2013, from: http://monographs.iarc.fr/

IARC – International Agency for Research on Cancer, 'Agents classified by the IARC monographs, Volumes 1–109', 2014a. Available at: http://monographs.iarc.fr/ENG/Classification/

IARC – International Agency for Research on Cancer (2014b), *Air Pollution and Cancer*, IARC Scientific Publication No 161, 2014.

ILO – International Labour Organisation, C139 – Occupational Cancer Convention, 1974, Convention concerning Prevention and Control of Occupational Hazards caused by Carcinogenic

Substances and Agents, Entry into force: 10 June 1976, Adoption: Geneva, 59th ILC session, 24 June 1974, Status: Up-to-date instrument, Technical Convention. Available at: http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO:12100:P12100_INSTRUMENT_ID:312284:NO

INCA – French National Cancer Institute (2013a). Cancer Pro Actu – Newsletter on the prevention of occupational cancers (in French). Available at: http://www.e-cancer.fr/prevention/expositions-professionnelles/espace-professionnels-de-sante/ressources-et-veille-documentaires/cancers-pro-actu

INCA – French National Cancer Institute (2013b). Cancers Doc Pro – Guide to resources on the primary prevention of occupational cancers (in French). Available at: http://www.e-cancer.fr/prevention/expositions-professionnelles/espace-professionnels-de-sante/ressources-et-veille-documentaires/cancers-pro-doc

INERIS, Environment and Health. 2nd National Action Plan 2009 – 2013. Concrete measures to prevent environment-related health risks, 2010. Available at http://www.sante.gouv.fr/IMG/pdf/presangl.pdf.

INVS (Institut de veille sanitaire), *Matrices emplois-expositions en population générale. État d'avancement*, Luce D, Févotte J and the Matgéné working group, September 2005, Saint-Maurice, 2006. Available at http://opac.invs.sante.fr/index.php?lvl=notice_display&id=5178

INVS (Institut de veille sanitaire), *Éléments techniques sur l'exposition professionnelle aux carburants et solvants pétroliers: Matrice emplois-expositions aux carburants et solvants pétroliers*, Pilorget C, Dananche B, Luce D, Févotte J and the Matgéné working group, Institut de veille sanitaire, Saint-Maurice, and Umrestte, Lyons, 2007a. Available at http://opac.invs.sante.fr/index.php?lvl=notice_display&id=3658

INVS (Institut de veille sanitaire), *Matrice emplois-expositions aux carburants et solvants pétroliers*, Matgéné working group, Saint-Maurice, 2007b. Available at http://opac.invs.sante.fr/index.php?lvl=notice_display&id=3753

INVS (Institut de veille sanitaire), *Présentation d'une matrice emplois-expositions aux fibres de laines minérales: Quelques applications à un échantillon de population en France*, Matgéné working group, Saint-Maurice, 2008,. Available at http://opac.invs.sante.fr/index.php?lvl=notice_display&id=1744

INVS (Institut de veille sanitaire), *Éléments techniques sur l'exposition professionnelle à cinq solvants chlorés (trichloréthylène, perchloréthylène, chlorure de méthylène, tétrachlorure de carbone, chloroforme): Matrices emplois-expositions à cinq solvants chlorés*, Dananché B., Févotte J. and the Matgéné working group, Institut de veille sanitaire, Saint-Maurice, and Umrestte, Lyon, 2009a. Available at: http://opac.invs.sante.fr/index.php?lvl=notice_display&id=1028

INVS (Institut de Veille Sanitaire), *Présentation de matrices emplois-expositions à cinq solvants chlorés: Quelques applications à un échantillon de population en France*, Matgéné working group, Saint-Maurice, 2009b. Available at http://opac.invs.sante.fr/doc_num.php?explnum_id=680

INVS (Institut de Veille Sanitaire), *Éléments techniques sur l'exposition professionnelle aux poussières alvéolaires de silice cristalline libre – Présentation d'une matrice emplois-expositions aux poussières alvéolaires de silice cristalline libre*, Delabre L, Pilorget C, Garras L, Févotte Jand the Matgéné working group, Saint-Maurice, 2010a. Available at http://opac.invs.sante.fr/index.php?lvl=notice_display&id=775

INVS, (Institut de Veille Sanitaire), *Présentation d'une matrice emplois-expositions aux poussières alvéolaires de silice cristalline libre: Quelques applications à un échantillon de population en France*, Matgéné working group. Saint-Maurice, 2010b. Available at http://opac.invs.sante.fr/index.php?lvl=notice_display&id=717

INVS (Institut de Veille Sanitaire), *Présentation d'une matrice emplois-expositions aux fibres céramiques réfractaires: Quelques applications à un échantillon de population en France*, Matgéné working group, Saint-Maurice, 2012a. Available at http://www.invs.sante.fr/Publications-et-outils/Rapports-et-syntheses/Travail-et-sante/2012/Elements-techniques-sur-l-exposition-professionnelle-aux-fibres-minerales-artificielles

INVS (Institut de Veille Sanitaire), *Éléments techniques sur l'exposition professionnelle aux fibres minérales artificielles: Matrices emplois-expositions aux fibres minérales artificielles – laines minérales, fibres céramiques réfractaires*, Ducamp, S. and the Matgéné working group, Saint-Maurice, 2012b. Available at http://www.invs.sante.fr/Publications-et-outils/Rapports-et-syntheses/Travail-et-sante/2012/Elements-techniques-sur-l-exposition-professionnelle-aux-fibres-minerales-artificielles

Karjalainen, A. & Niederlander, E., 'Occupational diseases in Europe in 2001', *Statistics in Focus* 15, 2004.

Kauppinen, T., Heikkilä, P., Plato, N., Woldbaek, T., Lenvik, K., Hansen, J., Kristjansson, V. & Pukkala, E., 'Construction of job-exposure matrices for the Nordic Occupational Cancer study (NOCCA)', *Acta Oncol* 48, 2009, pp. 791–800.

Kauppinen, T., Karjalainen, A., Pukkala, E., Virtanen, S., Saalo, A. & Vuorela, R., 'Evaluation of a national register on occupational exposure to carcinogens: Effectiveness in the prevention of cancer, and cancer risks among the exposed workers', *Ann Occup Hyg* 51, 2007, pp. 463–70.

Kauppinen, T., Pajarskiene, B., Podniece, Z., Rjazanov, V., Smerhovsky, Z., Veidebaum, T. & Leino, T., 'Occupational exposure to carcinogens in Estonia, Latvia, Lithuania and the Czech Republic in 1997', *Scand J Work Environ Health* 27, 2001, pp. 343–5.

Kauppinen, T., Toikkanen, J., Pedersen, D., Young, R., Ahrens, W., Boffetta, P., Hansen, J., Kromhout, H., Maqueda Blasco, J., Mirabelli, D., de la Orden-Rivera, V., Pannett, B., Plato, N., Savela, A., Vincent, R. & Kogevinas, M., 'Occupational exposure to carcinogens in the European Union', *Occ Environ Med* 57, 2000, pp. 10–18.

Kauppinen, T., Toikkanen, J. & Pukkala, E., 'From cross-tabulations to multipurpose exposure information system: A new job-exposure matrix', *Am J Ind Med* 33, 1998, pp. 409–17.

Kauppinen, T., Uuksulainen, S., Saalo, A. & Mäkinen, I. 'Trends of occupational exposure to chemical agents in Finland in 1950–2020', *Ann Occup Hyg* 57(5), June 2013, pp. 593–609. Available at: http://www.ncbi.nlm.nih.gov/pubmed/23230130

Kauppinen, T., Vincent, R., Liukkonen, T., Grzebyk, M., Kauppinen, A., Welling, I., Arezes, P., Black, N., Bochmann, F., Campelo, F., Costa, M., Elsigan, G., Goerens, R., Kikemenis, A., Kromhout, H., Miguel, S., Mirabelli, D., McEneany, R., Pesch, B., Plato, N., Schlünssen, V., Schulze, J., Sonntag, R., Verougstraete, V., De Vicente, M.A., Wolf, J., Zimmermann, M., Husgafvel-Pursiainen, K. & Savolainen, K., 'Occupational exposure to inhalable wood dust in the Member States of the European Union', *Ann Occup Hyg* 50, 2006, pp. 549–61. Available at: http://www.ncbi.nlm.nih.gov/pubmed/16571638

Koeman, T., Slottje, P., Kromhout, H., Schouten, L., Goldbohm, R., van den Brandt, P. & Vermeulen, R., 'Occupational exposure to extremely low-frequency magnetic fields and cardiovascular disease mortality in a prospective cohort study', *Occup Environ Med* 70, 2013, pp. 402–7.

Kooperationsstelle Hamburg IFE, *Analysis of sources and methods adequate for identifying and assessing exposure populations*, final report, February 2013 (in press, to be published by BAuA)

Koppisch, D., Schinkel, J., Gabriel, S., Fransman, W. & Tielemans, E. 'Use of the MEGA exposure database for the validation of the Stoffenmanager model', *Ann Occup Hyg* 56, 2012, pp. 426–39. Available at: http://annhyg.oxfordjournals.org/content/56/4/426.long

Konieczko K., Pałaszewska-Tkacz A., Czerczak S.: 'Chemical carcinogenic and mutagenic agents in the workplace, Poland, 2008–2010' in Medycyna Pracy; 64(2), 2013, p. 181–192

Kromhout, H., Symanski, E. & Rappaport, S., 'A comprehensive evaluation of within- and between-worker components of occupational exposure to chemical agents', *Ann Occup Hyg* 37, 1993, pp. 253–70.

Labrèche, F., Duguay, P., Ostiguy, C., Boucher, A., Roberge, B., Peters, C.E. & Demers, P.A. 'Estimating occupational exposure to carcinogens in Quebec', *Am J Ind Med* 56, 2013, pp. 1040–50. Available at: http://onlinelibrary.wiley.com/doi/10.1002/ajim.22200/abstract

Lavoué, J., Friesen, M. & Burstyn, I., 'Workplace measurements by the US Occupational Safety and Health Administration since 1979: Descriptive analysis and potential uses for exposure assessment', *Ann Occup Hyg* 57, 2013, pp. 77–97.

Lavoué, J., Pintos, J., van Tongeren, M., Kincl, L., Richardson, L., Kauppinen, T., Cardis, E., Siemiatycki, J., 'Comparison of exposure estimates in the Finnish job-exposure matrix FINJEM with a JEM derived from expert assessments performed in Montreal', *Occup Environ Med* 69, 2012, pp. 465–71.

Leconte, B, Thébaud-Mony, A., 'Work account and occupational exposures to carcinogens. Survey in Seine-Saint-Denis (France)', *Perspectives interdisciplinaires sur le travail et la santé (PISTES),* 12-3, 2010*.*

Lemarchand, C., Tual, S., Levêque-Morlais, N., Perrier, S., Guizard, A.V., Velten, M., Rigaud, E., Baldi, I., Lebailly, P., 'Prostate cancer risk among French farmers in the AGRICAN cohort'. Occup Environ Med. 71 Suppl 1, 2014, p.A86-7. 9.

Lynge, E. *Social inequalities and their impact on exposures to carcinogens and work-related cancer – What do we know*, presentation of NOCCA results at the EU-OSHA workshop Work-Related Cancer and Carcinogens, Berlin, 3–4 September 2012. Available at https://osha.europa.eu/en/seminars/workshop-on-carcinogens-and-work-related-cancer/speech-venues/session-1b-vulnerable-groups/social-inequalities-and-their-impact-on-exposures-to-carcinogens-and-work-related-cancer-2013-what-do-we-know

Marinaccio, A., Binazzi, A., Marzio, D.D., Scarselli, A., Verardo, M., Mirabelli, D., Gennaro, V., Mensi C., Riboldi, L., Merler, E., Zotti, R.D., Romanelli, A., Chellini, E., Silvestri, S., Pascucci, C., Romeo, E., Menegozzo, S., Musti, M., Cavone, D., Cauzillo, G., Tumino, R., Nicita, C., Melis, M., Iavicoli, S.;. 'Pleural malignant mesothelioma epidemic: incidence, modalities of asbestos exposure and occupations involved from the Italian National Register', *Int J Cancer*. 130(9), 2012,p. 2146-54.

Martinsen, J.I., Kjaerheim, K., Lynge, E., Gunnarsdottir, H.K., Sparen, P., Tryggvadottir, L., Weiderpass, E. & Pukkala, E. (2008). 'Occupations and socioeconomic status as risk factors for skin melanoma', *NOCCA Congress presentations and abstracts*. Retrieved 23 February 2014, from: http://astra.cancer.fi/NOCCA/abstracts.html

Mater, G.M., Jeandel, B., Clerc, F., Wild, P., Paris, Lavoué, J., 'Descriptive analysis of the French occupational exposure databanks COLCHIC and SCOLA', *Occup Environ Med,* 70, 2013, p. A2. Available at: http://oem.bmj.com/content/70/Suppl_1/A2.2.abstract.

McCausland, K., Martin, N. & Missair, A., 'Anaesthetic technique and cancer recurrence: current understanding', *OA Anaesthetics,* 2014 Jan 18;2(1):1. Available at: https://www.oapublishinglondon.com/article/1125

McDuffie, H.H., Pahwa, P., McLaughlin, J.R., Spinelli, J.J., Fincham, S., Dosman, J.A., Robson, D., Skinnider, L.F. & Choi, N.W., 'Non-Hodgkin's lymphoma and specific pesticide exposures in men: Cross-Canada study of pesticides and health', *Cancer Epidemiol Biomarkers Prev* 10, 2001, pp. 1155–63. Available at: http://www.ncbi.nlm.nih.gov/pubmed/11700263

MEGA database and publications, http://www.dguv.de/ifa/Gefahrstoffdatenbanken/Expositionsdatenbank-MEGA/index.jsphttp://www.dguv.de/ifa/en/gestis/mega/jour/index.jsp, accessed 27 October 2014

Melnick, R.L. & Huff, J., 'Lorenzo Tomatis and primary prevention of environmental cancer', *Environmental Health* 10, Supplement 1, 2011. Available at: http://www.ehjournal.net/content/10/S1/S14

Melzer, F., 'Nur jeder fünfte Antrag kommt durch [Only every fifth application is successful]', *Metallzeitung* 2, Frankfurt, 2014.

Menegaux, F., Truong, T., Anger, A., Cordina-Duverger, E., Lamkarkach, F., Arveux, P., Kerbrat, P., Guenel, P.Févotte, J., 'Night work and breast cancer: A population-based case–control study in France (the CECILE study) ', *Int. J. Cancer* 132, 2013, p. 924–931. Available at http://onlinelibrary.wiley.com/doi/10.1002/ijc.27669/pdf

Menegaux, F., Anger, A., Randrianasolo, H., Mulot, C., Laurent-Puig, P., Iborra, F., Bringer, J.-P., Leizour, B., Thuret, R., Lamy, P.-J., Rébillard, X., Trétarre, B., 'Epidemiological study of prostate cancer (EPICAP): a population-based case–control study in France', *BMC Cancer*, 14, 2014, p.106. Available at http://www.biomedcentral.com/1471-2407/14/106

Mirabelli, D. & Kauppinen, T., 'Occupational exposure to carcinogens in Italy: An update of CAREX database', *Int J Occup Environ Health* 11, 2005, pp. 53–63.

Muller, H., 'The problem of genetic modification', Fifth International Congress of Genetics in Berlin, 1926.

Musu, T., Overview of the main EU legislation relevant for occupational carcinogens, ETUI, 2014. Retrieved 7 October 2014, from: http://www.etui.org/News/ETUI-training-course-on-work-cancers

Nebot, M., López, M.J., Ariza, C., Pérez-Ríos, M., Fu, M., Schiaffino, A., Muñoz, G., Saltó, E., Fernández, E., 'Impact of the Spanish smoking law on exposure to secondhand smoke in offices and hospitality venues: before-and-after study'. *Environ Health Perspect* 117(3), 2009, p. 344-7.

NEDB, National Exposure Database, http://data.gov.uk/dataset/national-exposure-database@2013-09-05T13%3A51%3A54.148686

Nies, E., Musanke, U., Püringer, J., Rühl, R. & Arnone, M., 'DNELs for workplaces: Observations from an inspection of the DGUV DNEL list', *Gefahrstoffe: Reinhaltung der Luft*, 11–12(73), 2013. Available at: http://www.dguv.de/medien/ifa/de/pub/grl/pdf/2013_210.pdf

NOCCA Website, http://astra.cancer.fi/NOCCA/

Nurminen, M. & Karjalainen, A., 'Epidemiologic estimate of the proportion of fatalities related to occupational factors in Finland', *Scand J Work Environ Health* 27, 2001, pp. 161–213. Available at: http://www.ncbi.nlm.nih.gov/pubmed/11444413.

OCCAM Website, http://www.occam.it/en/index.php

OCRC – Occupational Cancer Research Centre (2014). 'Occupational cancer surveillance using the 1991–2006 Canadian census mortality and cancer cohort'. Retrieved 24 April 2014, from: http://www.occupationalcancer.ca/2011/occupational-cancer-surveillance-using-the-1991-2006-canadian-census-mortality-cancer-cohort/

OCRC – Occupational Cancer Research Centre (2014a). 'Sun at work: Outdoor worker sun safety'. Retrieved 24 April 2014, from: http://www.occupationalcancer.ca/2013/sun-at-work-outdoor-worker-sun-safety/?gwcpp_catid=93

Oddone, E., Edefonti, V., Scaburri, A., Tiziana, V., Crosignani, P. & Imbriani, M., 'Female breast cancer in Lombardy, Italy (2002–2009): A case–control study on occupational risks', *Am J Indust Med* 56(9), September 2013, pp. 1051–62. Available at: http://www.occam.it/en/resources/AmJIndMed2013.pdf

Pacheco S.A., Aguiar,F, Ruivo, P., Proença, M.C., Sekera, M., Penque, D., Simões, T., 'Occupational exposure to environmental tobacco smoke: a study in Lisbon restaurants', J Toxicol Environ Health A.;75(13-15), 2012, p. 857-66.

Pahwa, P., McDuffie, H.H., Dosman, J.A., McLaughlin, J.R., Spinelli, J.J., Robson, D. & Fincham, S., 'Hodgkin lymphoma, multiple myeloma, soft tissue sarcomas, insect repellents, and phenoxyherbicides', *J Occup Environ Med* 48, 2006, pp. 264–74. Available at: http://www.ncbi.nlm.nih.gov/pubmed/16531830

Pahwa, M., Mustard, C., Aronson, K., Kramer, D., Moore, K., Stegne, M. & Demers, P., *Workplace practices to address the health effects of shiftwork: What is the current state of knowledge and what is needed from a one day symposium?* Project funded by the Workplace Safety and Insurance Board of Ontario, 2012. Available at: http://occupationalcancer.ca/wp-content/uploads/2011/11/Shiftwork-survey-results1.pdf

Panizza, C., Bai, E., Oddone, E., Scaburri, A., Massari, S., Modonesi, C., Contiero, P., Marinaccio, A. & Crosignani, P., 'Lung cancer risk in the electroplating industry in Lombardy, Italy: Using the Italian Occupational Cancer Monitoring (OCCAM) Information System', *Am J Indust Med* 55, 2012, pp. 1–4. Available at: http://www.occam.it/en/resources/AmJIndMed2011.pdf

Partanen, T., Chaves, J., Wesseling, C., Chaverri, F., Monge, P., Ruepert, C., Aragon, A., Kogevinas, M., Hogstedt, C. & Kauppinen, T., 'Workplace carcinogen and pesticide exposures in Costa Rica', *Int J Occup Environ Health* 9, 2003, pp. 104–11.

PEROSH – Partnership for European Research in Occupational Safety and Health (2014), 'Development of a nano exposure and contextual information database (NECID)'. Retrieved 4 November 2014, from: http://www.perosh.eu/development-of-a-nano-exposure-and-contextual-information-database-necid/#

Peters, C.E., Ge, C. B., Hall, A. L., Davies, H. W., Demers, P. A., 'CAREX Canada: an enhanced model for assessing occupational carcinogen exposure', *Occup Environ Med* (2014) doi:10.1136/oemed-2014-102286, open access. Available at http://oem.bmj.com/content/early/2014/06/26/oemed-2014-102286.full

Peters, S., Vermeulen, R., Olsson, A., Van Gelder, R., Kendzia, B., Vincent, R., Savary, B., Williams, N., Woldbæk, T., Lavoué, J., Cavallo, D., Cattaneo, A., Mirabelli, D., Plato, N., Dahmann, D., Févotte, J., Pesch, B., Brüning, T., Straif, K. & Kromhout, H., 'Development of an exposure measurement database on five lung carcinogens (ExpoSYN) for quantitative retrospective occupational exposure assessment', *Ann Occup Hyg* 56(1), 2012, pp. 70–9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/21989165

Polańska K., Hanke W., Konieczko K., Hospitality workers' exposure to environmental tobacco smoke before and after implementation of smoking ban in public places: a review of epidemiological studies, *Med Pr*. 62(2), 2011, p.211-24.

Pretto, J., *French governmental plans and national labour inspectorate campaign on exposure of employees to hazardous substances*, presentation at the EU-OSHA workshop Carcinogens and Work-Related Cancer, Berlin, 3–4 September 2012. Retrieved 4 July 2013, from: https://osha.europa.eu/en/seminars/workshop-on-carcinogens-and-work-related-cancer/speech-venues/session-1c-cancer-prevention-action-plans-and-campaigns-to-prevent-work-related-cancer/french-governmental-plans-and-national-labour-inspectorate-campaign

Pukkala, E., Martinsen, J.I., Lynge, E., Gunnarsdottir, H.K., Sparén, P., Tryggvadottir, L., Weiderpass, E. & Kjaerheim, K., 'Occupation and cancer: Follow-up of 15 million people in five Nordic countries', *Acta Oncol* 48, 2009, pp. 646–790. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19925375 http://www.ncbi.nlm.nih.gov/pubmed/19925375 and http://astra.cancer.fi/NOCCA/full-article.html

Püringer, J., Derived Minimal Effect Levels (DMELs): Shortcomings one year after the REACH registration deadline, English translation by the author of Püringer J., "Derived Minimal Effect Levels" (DMEL): Defizite ein Jahr nach der REACH-Registrierungspflicht, *Gefahrstoffe – Reinhaltung der Luft* 71, p. 471–479, 2011. Available at http://www.auva.at/portal27/portal/auvaportal/content/contentWindow?&contentid=10008.544427&action=b&cacheability=PAGE

Rajan, B., Alesbury, R., Carton, B., Gerin, M., Litske, H.,Marquart, H., Olsen, E., Scheffers, T., Stamm, R. & Woldbaek, T., 'European proposal for core information for the storage and exchange of workplace exposure measurements on chemical agents', *Appl Occup Environm Hyg* 12(1), 1997, p. 31–9.

Rushton, L., Hutchings, S. & Brown, T., 'The burden of cancer at work: Estimation as the first step to prevention', *Occup Environ Med* 65, 2008, pp. 789–800.

Rushton, L., Hutchings, S., Fortunato, L., Young, C., Evans, G., Brown, T., Bevan, R., Slack, R., Holmes, P., Bagga, S., Cherrie, J.W. & van Tongeren, M., 'Occupational cancer burden in Great Britain', *Br J Cancer* 107, 2012, pp.3–7. Available at: http://www.nature.com/bjc/journal/v107/n1s/full/bjc2012112a.html

Saalo, A., Soosaar, A., Länsimäki E. & Kauppinen, T., *ASA 2005* [in Finnish], Finnish Institute of Occupational Health, Helsinki, 2007.

Saalo, A., Soosaar, A., Länsimäki, E. & Kauppinen, T., *ASA 2010* [in Finnish], Finnish Institute of Occupational Health, Helsinki, 2012.

Scarselli, A. 'The National Registry of Occupational Exposures to Carcinogens (SIREP): Information system and results [in Italian]', *G Ital Med Lav Ergon* 33, Supplement 3, 2011, pp. 78–9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/23393806

Scarselli, A., Binazzi, A., Ferrante, P. & Marinaccio, A, 'Occupational exposure levels to wood dust in Italy, 1996–2006', *Occup Environ Med* 65, 2008, pp. 567–74.

Scarselli, A., Montaruli, C. & Marinaccio, A., 'The Italian information system on occupational exposure to carcinogens (SIREP): Structure, contents and future perspectives', *Ann Occup Hyg* 51(5), 2007, pp. 471–8.

Schenk, L. & Johanson, G., 'A quantitative comparison of the safety margins in the European indicative occupational exposure limits and the derived no-effect levels for workers under REACH', *Toxicological Sciences* 121(2), 2011, pp. 408–16.

SDBtransfer, Development of a demonstration solution for digital exchange of safety data in the supply chain. Available at http://www.bgbau.de/gisbau/fachthemen/sdbtransfer

SHEcan: 'Health, socioeconomic and environmental impact of possible amendments to the EU Carcinogens and Mutagens Directive', Executive summary, 2011a .Retrieved 29 October 2014 from ec.europa.eu/social/BlobServlet?docId=10150&langId=en

SHEcan: 'Health Socioeconomic and environmental impact of possible amendments to the EU Carcinogens and Mutagens Directive', Summary report, 2011b .Retrieved 29 October 2014 from ec.europa.eu/social/BlobServlet?docId=10149&langId=en

Siemiatycki, J., Richardson, L., Straif, K., Latreille, B., Lakhani, R., Campbell, S., Rousseau, M-C. & Boffetta, P., 'Listing occupational carcinogens', *Environmental Health Perspectives*, 112(15), 2004. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1247606/pdf/ehp0112-001447.pdf

Singh K., Oates C., Plant J., Voulvoulis N., 'Undisclosed chemicals--implications for risk assessment: a case study from the mining industry', *Environ Int.* 68, p.1-15, 2014. Available at http://www.sciencedirect.com/science/article/pii/S0160412014000622.

Suleiman A. M, Svendsen K. V., 'Are safety data sheets for cleaning products used in Norway a factor contributing to the risk of workers exposure to chemicals?', *Int J Occup Med Environ Health*. 27(5), p. 840-53, 2014

Surdu, S., Fitzgerald, E.F., Bloom, M. S., Boscoe, F. P., Carpenter, D.O., Haase, R.F., Gurzau, E., Rudnai, P., Koppova, K., Févotte, J., Leonardi, G., Vahter, M., Goessler, W., Kumar, R., Fletcher, T., 'Occupational Exposure to Ultraviolet Radiation and Risk of Non-Melanoma Skin Cancer in a Multinational European Study', PLoS ONE 8(4): e62359. Available at http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0062359

Tieves, D., *Women and occupational diseases in the European Union*, Report 118, European Trade Union Institute, 2011. Available at: http://www.etui.org/Publications2/Reports/Women-and-occupational-diseases-in-the-European-Union

United Nations, Globally Harmonized System of Classification and Labelling of Chemicals (GHS), Fifth revised edition, 2013. Available at http://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html.

Van Tongeren, M., Kincl, L., Richardson, L., Benke, G., Figuerola, J., Kauppinen, T., Lakhani, R., Lavoué, J., McClean, D., Plato, N. & Cardis, E., 'Assessing occupational exposure to chemicals in an international epidemiological study of brain tumours', *Ann Occup Hyg,* 57(5), 2013, pp. 610–26.

Vincent, R., 'Inventaires des agents chimiques CMR utilisés en France', *Hygiène et sécurité du travail: Cahiers de notes documentaires* 205, 2006, p. 83–96. Available at http://www.inrs.fr/accueil/dms/inrs/CataloguePapier/ND/TI-PR-26/pr26.pdf

Vincent, R. & Jeandel, B., 'COLCHIC: Occupational exposure to chemical agents database – current content and development perspectives', *Appl Occup Environ Hyg* 16, 2001, pp. 115–21.

Vinzents, P.S., Carton, B., Fjeldstad, P., Rajan, B. & Stamm, R., 'Comparison of exposure measurements stored in European databases on occupational air pollutants and definitions of core information', *App Occ Env Hyg* 10(4), 1995, pp. 351–4.

Vlaanderen, J., Straif, K., Pukkala, E., Kauppinen, T., Kyyrönen, P., Martinsen, J.I., Kjaerheim, K., Tryggvadottir, L., Hansen, J., Sparén, P. & Weiderpass, E. 'Occupational exposure to trichloroethylene and perchloroethylene and the risk of lymphoma, liver, and kidney cancer in four Nordic countries', *Occup Environ Med,* 70(6), 2013, pp. 393–401.

Walters, D., Johnstone, R., Frick, K., Quinlan, M., Baril-Gingras, G., Thébaud-Mony, A. *Regulating Workplace Risks. A Comparative Study of Inspection Regimes in Times of Change,* Edward Elgar Publishing, Cheltenham, UK, 2011

WHO – World Health Organisation – & UNEP – United Nations Environment Programme, *State of the science of endocrine disrupting chemicals 2012*, eds Bergman, A., Heindel, J.J., Jobling, S., Kidd, K.A. & Zoeller, R.T., Inter-Organization Programme for the Sound Management of Chemicals, 2012. Available at: http://www.who.int/ceh/publications/endocrine/en/index.html

Wriedt, H., *The German exposure risk management model,* presentation at the EU-OSHA workshop Carcinogens and Work-Related Cancer, Berlin, 3–4 September 2012. Retrieved 4 July 2013, from: https://osha.europa.eu/en/seminars/workshop-on-carcinogens-and-work-related-cancer/speech-venues/session-1c-cancer-prevention-action-plans-and-campaigns-to-prevent-work-related-cancer/french-governmental-plans-and-national-labour-inspectorate-campaign

Yousif, L., Hammer, G.P., Emrich, K., Blettner, M. & Zeeb, H., 'Occupational risk factors for testicular cancer: A registry-based case-control study in Rhineland Palatinate – Germany', *German Medical Science* 12, 2013. Retrieved 31 March 2014, from: http://www.egms.de/static/en/journals/gms/2013-11/000184.shtm

Annex I

European Schedule of Occupational Diseases:

I. Diseases caused by exposure to chemical and biological agents

1 Diseases caused by the following chemical agents:

100 Acrylonitrile

101 Arsenic or compounds thereof

102 Beryllium (glucinium) or compounds thereof

103.01 Carbon monoxide

103.02 Carbon oxychloride

104.01 Hydrocyanic acid

104.02 Cyanides and compounds thereof

104.03 Isocyanates

105 Cadmium or compounds thereof

106 Chromium or compounds thereof

107 Mercury or compounds thereof

108 Manganese or compounds thereof

109.01 Nitric acid

109.02 Oxides of nitrogen

109.03 Ammonia

110 Nickel or compounds thereof

111 Phosphorus or compounds thereof

112 Lead or compounds thereof

113.01 Oxides of sulphur

113.02 Sulphuric acid

113.03 Carbon disulphide

114 Vanadium or compounds thereof

115.01 Chlorine

115.02 Bromine

115.04 Iodine

115.05 Fluorine or compounds thereof

116 Aliphatic or alicyclic hydrocarbons derived from petroleum spirit or petrol

117 Halogenated derivatives of the aliphatic or alicyclic hydrocarbons

118 Butyl, methyl and isopropyl alcohol

119 Ethylene glycol, diethylene glycol, 1,4-butanediol and the nitrated derivatives of the glycols and of glycerol

120 Methyl ether, ethyl ether, isopropyl ether, vinyl ether, dichloroisopropyl ether, guaiacol, methyl ether and ethyl ether of ethylene glycol

121 Acetone, chloroacetone, bromoacetone, hexafluoroacetone, methyl ethyl ketone, methyl n-butyl ketone, methyl isobutyl ketone, diacetone alcohol, mesityl oxide, 2-methylcyclohexanone

122 Organophosphorus esters

123 Organic acids

124 Formaldehyde

125 Aliphatic nitrated derivatives

126.01 Benzene or counterparts thereof (the counterparts of benzene are defined by the formula: CnH2n-6)

126.02 Naphthalene or naphthalene counterparts (the counterpart of naphthalene is defined by the formula: CnH2n-12)

126.03 Vinylbenzene and divinylbenzene

127 Halogenated derivatives of the aromatic hydrocarbons

128.01 Phenols or counterparts or halogenated derivatives thereof

128.02 Naphthols or counterparts or halogenated derivatives thereof

128.03 Halogenated derivatives of the alkylaryl oxides

128.04 Halogenated derivatives of the alkylaryl sulfonates

128.05 Benzoquinones

129.01 Aromatic amines or aromatic hydrazines or halogenated, phenolic, nitrified, nitrated or sulfonated derivatives thereof

129.02 Aliphatic amines and halogenated derivatives thereof

130.01 Nitrated derivatives of aromatic hydrocarbons

130.02 Nitrated derivatives of phenols or their counterparts

131 Antimony and derivatives thereof

132 Nitric acid esters

133 Hydrogen sulphide

135 Encephalopathies due to organic solvents which do not come under other headings

136 Polyneuropathies due to organic solvents which do not come under other headings

2 Skin diseases caused by substances and agents not included under other headings

201 Skin diseases and skin cancers caused by:

201.01 Soot

201.03 Tar

201.02 Bitumen

201.04 Pitch

201.05 Anthracene or compounds thereof

201.06 Mineral and other oils

201.07 Crude paraffin

201.08 Carbazole or compounds thereof

201.09 By-products of the distillation of coal

202 Occupational skin ailments caused by scientifically recognised allergy-provoking or irritative substances not included under other headings

3 Diseases caused by the inhalation of substances and agents not included under other headings

301 Diseases of the respiratory system and cancers

301.11 Silicosis

301.12 Silicosis combined with pulmonary tuberculosis

301.21 Asbestosis

301.22 Mesothelioma following the inhalation of asbestos dust

301.31 Pneumoconioses caused by dusts of silicates

302 Complication of asbestos in the form of bronchial cancer

303 Broncho-pulmonary ailments caused by dusts from sintered metals

304.01 Extrinsic allergic alveolites

304.02 Lung diseases caused by the inhalation of dusts and fibres from cotton, flax, hemp, jute, sisal and bagasse

304.04 Respiratory ailments caused by the inhalation of dust from cobalt, tin, barium and graphite

304.05 Siderosis

305.01 Cancerous diseases of the upper respiratory tract caused by dust from wood

304.06 Allergic asthmas caused by the inhalation of substances consistently recognised as causing allergies and inherent to the type of work

304.07 Allergic rhinitis caused by the inhalation of substances consistently recognised as causing allergies and inherent to the type of work

306 Fibrotic diseases of the pleura, with respiratory restriction, caused by asbestos

307 Chronic obstructive bronchitis or emphysema in miners working in underground coal mines

308 Lung cancer following the inhalation of asbestos dust

309 Broncho-pulmonary ailments caused by dusts or fumes from aluminium or compounds thereof

310 Broncho-pulmonary ailments caused by dusts from basic slags

4 Infectious and parasitic diseases

401 Infectious or parasitic diseases transmitted to man by animals or remains of animals

402 Tetanus

403 Brucellosis

404 Viral hepatitis

405 Tuberculosis

406 Amoebiasis

407 Other infectious diseases caused by work in disease prevention, health care, domicilary assistance and other comparable activities for which a risk of infection has been proven

I. Additional list of diseases suspected of being occupational in origin which should be subject to notification and which may be considered at a later stage for inclusion in Annex I to the European schedule

2.1 Diseases caused by the following agents:

2.101 Ozone

2.102 Aliphatic hydrocarbons other than those referred to under heading 1.116 of Annex I

2.103 Diphenyl

2.104 Decalin

2.105 Aromatic acids – aromatic anhydrides or their halogenated derivatives

2.106 Diphenyl oxide

2.107 Tetrahydrofurane

2.108 Thiopene

2.109 Methacrylonitrile

2.110 Acetonitrile

2.111 Thioalcohols

2.112 Mercaptans and thioethers

2.113 Thallium or compounds thereof

2.114 Alcohols or their halogenated derivatives not referred to under heading 1.118 of Annex I

2.115 Glycols or their halogenated derivatives not referred to under heading 1.119 of Annex I

2.116 Ethers or their halogenated derivatives not referred to under heading 1.120 of Annex I

2.117 Ketones or their halogenated derivatives not referred to under heading 1.121 of Annex I

2.118 Esters or their halogenated derivatives not referred to under heading 1.122 of Annex I

2.119 Furfural

2.120 Thiophenols or counterparts or halogenated derivatives thereof

2.121 Silver

2.122 Selenium

2.123 Copper

2.124 Zinc

2.125 Magnesium

2.126 Platinum

2.127 Tantalum

2.128 Titanium

2.129 Terpenes

2.130 Boranes

2.140 Diseases caused by inhaling nacre dust

2.141 Diseases caused by hormonal substances

2.150 Dental caries associated with work in the chocolate, sugar and flour industries

2.160 Silicium oxide

2.170 Polycyclic aromatic hydrocarbons which do not come under other headings

2.190 Dimethylformamide

2.2 Skin diseases caused by substances and agents not included under other headings

2.201 Allergic and orthoallergic skin ailments not recognised in Annex I

2.3 Diseases caused by inhaling substances not included under other headings

2.301 Pulmonary fibroses due to metals not included in the European schedule

2.303 Broncho-pulmonary ailments and cancers associated with exposure to the following:

- soot
- tar
- bitumen
- pitch
- anthracene or compounds thereof
- mineral and other oils

2.304 Broncho-pulmonary ailments caused by man-made mineral fibres

2.305 Broncho-pulmonary ailments caused by synthetic fibres

2.307 Respiratory ailments, particularly asthma, caused by irritants not listed in Annex I

2.308 Cancer of the larynx following the inhalation of asbestos dust

2.4 Infectious and parasitic diseases not described in Annex I

2.401 Parasitic diseases

2.402 Tropical diseases

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The European Agency for Safety and Health at Work (EU-OSHA) contributes to making Europe a safer, healthier and more productive place to work. The Agency researches, develops, and distributes reliable, balanced, and impartial safety and health information and organises pan-European awareness raising campaigns. Set up by the European Union in 1996 and based in Bilbao, Spain, the Agency brings together representatives from the European Commission, Member State governments, employers' and workers' organisations, as well as leading experts in each of the EU Member States and beyond.

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