National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Identifying prevalent carcinogens at the workplace in Europe

RIVM Letter report 2015-0107

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Inventarisatie meest voorkomende kankerverwekkende stoffen op de werkvloer in Europa

Het RIVM heeft een *short list* opgesteld van kankerverwekkende stoffen en mengsels waar mensen in Europa op de werkplek het meest aan kunnen blootstaan. Hieronder vallen ook bepaalde arbeidsprocessen waar chemische stoffen aan te pas komen, zoals lassen, schilderen en werken met olie. Met behulp van deze lijst kunnen stoffen worden geselecteerd die in Europees verband als eerste aangepakt kunnen worden door bindende arbeidskundige normen (grenswaarden) vast te stellen.

Stoffen of processen die veel voorkomen zijn onder andere benzeen, formaldehyde, asbest, houtstof en uitlaatgassen; deze behoren tot de top 30 van het totaal van 175 stoffen waarover informatie beschikbaar is. Voor zover bekend, vormen deze stoffen de voornaamste blootstelling aan kankerverwekkende stoffen, mengsels en arbeidsprocessen.

Het onderzoek betreft kankerverwekkende stoffen, mengsels of werkzaamheden ‘zonder drempelwaarde’. Hiervoor geldt dat er altijd, dus ook bij de geringste concentratie, een risico is als mensen eraan worden blootgesteld. Europese wetgeving schrijft voor om dergelijke stoffen waar mogelijk te vervangen. Wanneer dit niet kan, dient de werkgever de mogelijke blootstellingen en risico’s zo laag mogelijk te houden. Op dit moment verschilt per lidstaat hoe de grenswaarden voor kankerverwekkende stoffen worden afgeleid.

De lijst is in opdracht van het ministerie van SZW opgesteld en is bedoeld om de veiligheid van werkers te vergroten. Er zijn zes Europese databases geraadpleegd met gegevens als het aantal werkers dat wordt blootgesteld aan een stof en zogeheten indicatoren voor blootstelling. Deze variëren van taken, zoals het mengen van vloeistoffen, tot het gebruik van chemische stoffen (bijvoorbeeld in/door de chemische industrie).

Kernwoorden: carcinogenen, databases, werkerblootstelling

Synopsis

Identifying prevalent carcinogens at the workplace in Europe

The RIVM compiled a shortlist of substances, mixtures and processes identifying carcinogens with the most occupational exposure across Europe. The list also includes processes such as welding, painting and processing mineral oils. Those substances, mixtures and processes ranking highest can be selected at a European level for risk reduction by setting binding occupational exposure limit values.
The highest ranking substances, mixtures and processes are, among others, benzene, formaldehyde, engine exhaust, and wood dust. These belong to the top 30 of 175 ranked substances, mixtures and processes for which information was available. These substances, mixtures and processes are considered the most prevalent carcinogens at the workplace based on the available data, contributing most to exposure.

The report focuses specifically on non-threshold carcinogens. Non-threshold carcinogens are without a safe level of use. European worker legislation prescribes that those substances should be substituted wherever possible. If this is not possible, employers must ensure that exposure is as low as reasonable achievable. At this moment, the approaches to derive occupational limit values for carcinogens differ among Member States.

The Dutch Ministry of Social Affairs and Employment requested the RIVM to compile the shortlist aiming to increase worker safety. Data from six European databases were used, containing information on the number of workers exposed and other indicators. These range from specific worker tasks such as mixing of fluids to uses in chemical industries.

Keywords: carcinogens, databases, occupational exposure, workplace.

Contents

Summary

The chemical legislation related to worker safety aims at reducing the use and exposure to carcinogenic substances. Current discussions at European level concern the identification of those carcinogenic substances or processes with the highest potential exposure at workplaces in Europe. A number of selected EU databases containing exposure data on carcinogens have been consulted to compose a short list of carcinogens with the most prevalent occupational exposure. The intention was to identify those carcinogens for which the derivation and setting of a binding OEL can contribute most to a significant reduction in exposure to carcinogens, and thus to a better health protection of workers.

The starting list consisted of 385 substances classified by IARC and judged relevant for occupational exposure. Data availability on these substances was checked in six databases, i.e. SUMER survey (France), SIREP (Italy), ASA (Finland), the Polish register of carcinogenic or mutagenic agents (Poland), the EDPB (Belgium) and the ECHA database (Europe). For 175 substances it was possible to obtain quantitative data in at least one of the databases. It is noted that the database differ regarding type of information, data collection, and data limitations, making it difficult to use the raw data directly for ranking. The indicated number of workers exposed or exposure indicators such as process activities (in case of the ECHA database) were used for ranking the individual databases and the generation of a combined list of substances.

A weighted score and normalisation of the individual database rankings was used in the ranking method. In this way all data were given equal weight. Further, absence of data in a specific database was accounted for by scoring all absent substances equally with the lowest ranking score possible for that specific database. As a consequence, a ranking was obtained that implicitly favours substances present in most databases. The resulting ranking showed some well-known substances and processes ranking high, such as benzene (highest ranking substance), formaldehyde, asbestos, wood dust and engine exhaust.

It is noted that, based on the available data or the lack of data on the number of workers exposed per substance, it is difficult to present a strict order of substances with sufficient confidence within the (arbitrary chosen) top 70. From some large European countries no data was available. Carefully it may be concluded that considering the available data and associated uncertainties that the top ranking substances will indeed contain the most prevalent carcinogens at the workplace in Europe. These substances have relatively high numbers of workers exposed as compared to other substances supported by at least two of the six databases. By using weighted scoring, a list of carcinogens is compiled to which the highest numbers of workers are exposed to in Europe.

1 Introduction

It is estimated that occupational exposure to carcinogens leads to approximately 100.000 deaths in Europe each year, on a total of 1.75 million cancer deaths in 2012 (1). In addition, it is estimated that between 2 and 10% of all cancers are caused by occupational exposure (2). The focus of this report lies specifically on non-threshold carcinogens[1]. These carcinogens are considered to be without a safe level.

The chemical legislation related to worker safety aims at reducing the use and exposure to carcinogenic substances (threshold and non-threshold carcinogens), according to the Chemicals Agents Directive (CAD, 98/24/EC) and the Carcinogens and Mutagens Directive (CMD, 2004/37/EC). The CMD and its implementation in the European national legislations requires that exposure to carcinogens and mutagens is as low as reasonably achievable (ALARA principle), if replacement of such substances is not technically. There are many ways to regulate exposure to carcinogenic substances in the workplace: these substances could be prohibited, uses with (potentially) high exposure can be restricted, or the use of general measures to reduce exposure and/or personal protection equipment can be imposed. Occupational exposure levels (OELs) are important tools to regulate exposure at the workplace but at present, there is no widely agreed approach how to set these exposure limits at European level for non-threshold carcinogens (3).

Accurate information on exposure to carcinogens at the workplace can help to initiate risk management measures by employers and authorities to control the exposure to protect workers. Exposure registers may help to identify those workplaces where exposure to carcinogens can occur, and to some extent they encourage preventive measures to be taken. Current discussions at European level concern the identification of those carcinogenic substances with the highest potential exposure at workplaces in Europe. In a previous letter report, databases containing information on use and exposure to carcinogens at the workplace in the EU were identified (4). This report focuses on the identification of those substances that should be considered first for possible risk management measures from a use and exposure perspective.

Within the EU, the organization of the collection and storage of occupational exposure data differs per country. Some European countries have regional or national databases with exposure information collected by governmental organizations or insurance companies. In addition, several research initiatives have been initiated to gather information on occupational exposure to carcinogens (4). Following the recommendations from the previous letter report, a number of

[1] Though the terms 'non-threshold carcinogen' and 'substance' are used in this report, carcinogenic processes and formation products are not excluded from the scope of this project. A distinction between single substances and complex mixtures or processes is made specific where appropriate.

databases were consulted with the aim to derive a short list of non-threshold carcinogens with the most prevalent occupational exposure.

The aim of the project is to generate a short list of carcinogens based on exposure data, for which the derivation of a binding OEL can contribute to a significant reduction in exposure to carcinogens and thus to a better health protection of workers.

1.1 Methods

The collection of data on non-threshold carcinogens was focused on composing a shortlist of substances with the most prevalent occupational exposure, based on information obtained from available databases across Europe. The short list was based on a predefined list of 385 carcinogens. Since 1971, the International Agency for Research on Cancer (IARC) has evaluated over 900 agents, of which more than 400 have been classified as known or suspected carcinogens. Of these, a list of 385 substances, mixtures and processes (e.g. painting, exhaust gasoline, welding fumes) with potential relevance for the workplace has been compiled.

In 2014, the RIVM made an inventory of databases containing information on occupational exposure to carcinogens across Europe (4). Several of these databases were available for the current project. Owners of databases of SUMER survey, SCOLA and COLCHIC (France), MEGA database (Germany), SIREP (Italy), ASA (Finland), SPIN database (Nordic countries), the Polish register of carcinogenic or mutagenic agents (Poland) and the EDPB (Belgium) were approached for collaboration (see overview of substances in Chapter 2, Table 3). The data availability is indicated in Chapter 2.

The data from available databases were combined using a weighted scoring method resulting in the short list, which is described in Chapter 3. Finally in Chapter 4 the results were discussed. Information on the underlying databases can be found in Annex I.

2 Data availability; which substances, mixtures or processes are present in what database?

The starting list consists of the 385 carcinogenic substances, mixtures or processes to which workers are potentially exposed, with IARC (the International Agency for Research on Cancer) classifications 1 (carcinogenic), 2A (probably carcinogenic) and 2B (possibly carcinogenic to humans). Further, 147 of these substances have a harmonized EU classification according to CLP (1272/2008/EC), whereas 238 do not. However, it was not checked whether these 147 substances have a CLP-classification for carcinogenicity, as this would entail accessing each registration file individually, which was beyond the scope of this project. EU classification of carcinogens is divided in Cat. 1A (known to have CMR potential for humans, based largely on human evidence), 1B (presumed to have CMR potential for humans, based largely on experimental animal data) and Cat. 2 (suspected to have CMR potential for humans). It should be noted that EU classification according to CLP does not automatically follow from IARC classification, but in the framework of CMD legislation it may be relevant as the CMD relies on CLP classification rather than IARC classification.

The objective was to generate a list that encompasses exposure to carcinogens across Europe. Therefore, databases within the EU were selected. However, the information there contained, as well as accessibility to certain databases turned out to be limiting factors. For example, although the SPIN (Substances in Preparations in the Nordic Countries) database was originally included, it turned out that this database contains only a rough estimate for potential exposure and does not contain information on the number of exposed employees. It was therefore decided not to use the SPIN database for this project. A few other databases were not accessible, due to confidentiality, which concerned the German MEGA database and the French COLCHIC and SCOLA database.

The presence of the individual substances, mixtures or processes was checked in six different databases. Databases that were utilized were the ECHA database within the framework of the REACH regulation (Europe), the SUMER Survey (France), the SIREP database (Italy), the ASA database (Finland), the Polish register of carcinogenic or mutagenic agents (Poland) and the EDPB (Belgium) (for details, see Annex I). The ECHA database was added since it provides information on substances used across Europe. It should be stressed that the information obtained from some of these databases cannot be made publicly available, because of confidentiality of the data.

Not all of the described processes have an assigned CAS (Chemical Abstracts Service) number, but rather refer to an activity where exposure arises to an often undefined group of substances. Data on processes are sparse; REACH, EDPB and ASA do not have any information on processes, but the SUMER Survey and the Polish database provided some information. Concerning processes, the SIREP database only contained information on the number of measurements and not on the number of exposed employees. As a result, information on processes from the SIREP database was not used to compose a shortlist of substances with the most prevalent occupational exposure. A CAS number is a more specific identifier of a substance than just the description of a process. It should be taken into account that the substances assumed to be involved in a specific process could differ per database, hampering comparisons of information on processes between databases.

In addition, the availability of an occupational exposure limit (OEL) was checked for all of the 385 substances. OELs set in The Netherlands, Germany, UK, France, Poland, Italy and derived by the Scientific Committee on Occupational Exposure Limits (SCOEL) were readily available and therefore considered in this report. Although processes often refer to an undefined group of substances, which complicates derivation of an OEL, an OEL has been set for 10 of the 47 processes in the list (*e.g.* for welding fumes and wood dust). Here, it should be noted that SCOEL has set "no-OEL" for 20 substances in the list, indicating that they deemed it impossible to derive an OEL for that particular substance. The reasons for this can be found in the regarding SCOEL reports. It could for instance be due to a lack of data or to the genotoxic working mechanism of the substance. For 7 substances, derivation of an OEL by SCOEL is still ongoing. For some substances, OELs from the different countries are rather similar, but for other substances, the OELs differ substantially. Please note that the OELs presented may not account for genotoxic effects (3, 5)

Table 1 shows the number of substances, mixtures or processes present in the databases, and the number of substances and mixtures that have been assigned a CAS number.

Table 1 Number of substances that are classified according to IARC (starting list) and number of substances from the starting list that are classified according to CLP, with an OEL, and for which data is available or not.

	Total # substances	# without CAS number	# with CAS number
# substances IARC list	385	47	338
# substances with an OEL[1]	106	10	96
# substances with a harmonized classification (CLP)	147	3	144
# substances with data	192 [2] 178 [3]	19	171
# substances without data	194	28	166

[1] OELs from The Netherlands, Germany, France, UK, Poland, Italy and SCOEL were available.

[2] This includes either an OEL, or presence of the substance in one or more database(s)

[3] Presence in (a) database(s); this means that 14 substances have an OEL assigned, but are not present in any of the databases checked

The number of substances as well as the type of exposure information varies from database to database. As such, the information that was obtained from each database is not uniform. In some databases only the number of exposed workers is available, whereas others are more extensive and also contain information on the duration and intensity of exposure, and whether protection equipment is used. The ECHA database on the other hand, does not have information on the number of exposed workers, but only on the type of exposure. Table 2 gives a more detailed overview of the data availability for the 385 substances in each database, including what information was used to rank the substances, and the year or period of data collection.

Table 2 Number of substances, mixtures or processes with or without CAS number per databases, and the exposure indicators based upon which the databases were ranked.

Database	**Total # substances, mixtures, processes**	**# with CAS number**	**# without CAS number**	**Ranked on**	**Time period data collection**	**Data Confidential?**
ECHA, Europe	98	98	0	PROCs, Identified uses, Tonnage band	N/A[1]	Yes, partially
SUMER, France	53	28	25	# exposed workers	January 2009 – April 2010	No
ASA, Finland	48	48	0	# exposed workers	2013	No
SIREP, Italy	29	29	0	# exposed workers	1996-2013	Yes
EDPB, Belgium	17	17	0	# exposed workers	2013 (and 2012)	Yes
CM register, Poland	82	78	4	# exposed workers	2013	Yes

[1]REACH came into force in 2007; see Annex I, PROC =Process activity

The presence of the substances in the respective databases is provided in the table below (Table 3); the substances are sorted on the number of databases in which they are present. There is only one substance present on all lists and databases, six substances are present in five database, 19 in four, 24 in three, 49 in two, 79 in one database and for 14 substances only OELs have been reported. Please note that some substances seem to occur more than once on the list. This results from the use of different CAS numbers, whereas the name is more or less the same, e.g. asbestos is found several times on the list.

Table 3 Data availability per substance (ranked on the number of databases in which they are present).

				Database							
				OEL*	REACH, Europe	SIREP, Italy	SUMER, France	EDPB, Belgium	ASA, Finland	CM, Poland	CLP
				Total # of substances present in database:							
	CAS No	Name	Group	106	98	61	53	21	44	82	123
1	71-43-2	Benzene	1								
2	7440-41-7	Beryllium and beryllium	1								
3	7440-43-9	Cadmium and cadmium	1								
4	101-77-9	4,4'-Methylenedianiline	2b								
5	75-21-8	Ethylene oxide	1								
6	75-01-4	Vinyl chloride	1								
7	107-13-1	Acrylonitrile	2b								
8	79-06-1	Acrylamide	2a								
9	65996-93-2	Coal-tar pitch	1								
10	101-14-4	4,4'-Methylenebis(2-	1								
11	107-06-2	1,2-Dichloroethane	2b								
12	106-99-0	1,3-Butadiene	1								
13	77-78-1	Dimethyl sulfate	2a								
14	95-80-7	2,4-Diaminotoluene	2b								
15	50-00-0	Formaldehyde	1								
16	75-09-2	Dichloromethane	2b								
17	7440-38-2	Arsenic and inorganic	1								
18	12001-28-4	Asbestos (all forms,	1								
19	118-74-1	Hexachlorobenzene	2b								
20	106-89-8	Epichlorohydrin	2a								
21	98-07-7	alpha-Chlorinated	2a								
22	79-44-7	Dimethylcarbamoyl	2a								
23	96-09-3	Styrene-7,8-oxide	2a								
24	62-55-5	Thioacetamide	2b								
25	127-18-4	Tetrachloroethylene	2a								
26	56-23-5	Carbon tetrachloride	2b								
27	302-01-2	Hydrazine	2b								
28	95-53-4	ortho-Toluidine	1								
29	100-44-7	alpha-Chlorinated	2a								
30	90-04-0	ortho-Anisidine	2b								
31	75-55-8	2-Methylaziridine	2b								
32	593-60-2	Vinyl bromide	2a								
33	7440-48-4	Cobalt metal with	2a								
34	100-41-4	Ethylbenzene	2b								
35	7439-92-1	Lead	2b								
36	7440-02-0	Nickel, metallic and	2b								
37	100-42-5	Styrene	2b								
38	14808-60-7	Silica dust, crystalline,	1								
39	1332-21-4	Asbestos (all forms,	1								
40	12172-73-5	Asbestos (all forms,	1								
41	12001-29-5	Asbestos (all forms,	1								
42	64-67-5	Diethyl sulfate	2a								
43	96-23-1	1,3-Dichloro-2-propanol	2b								
44	838-88-0	4,4'-Methylene bis(2-	2b								
45	60-09-3	para-Aminoazobenzene	2b								
46	8052-42-4	Bitumens, occupational	2b								
47	1333-86-4	Carbon black	2b								
48	67-66-3	Chloroform	2b								
49	7440-48-4	Cobalt metal without	2b								
50	7440-48-4	Cobalt and cobalt	2b								

				Database							
				OEL*	REACH, Europe	SIREP, Italy	SUMER, France	EDPB, Belgium	ASA, Finland	CM, Poland	CLP
				Total # of substances present in database:							
	CAS No	Name	Group	106	98	61	53	21	44	82	123
51	106-47-8	para-Chloroaniline	2b								
52	123-91-1	1,4-Dioxane	2b								
53	77-09-8	Phenolphthalein	2b								
54	569-61-9	CI Basic Red 9	2b								
55	50-18-0	Cyclophosphamide	1								
56	556-52-5	Glycidol	2a								
57	96-12-8	1,2-Dibromo-3-	2b								
58	57-14-7	1,1-Dimethylhydrazine	2b								
59	122-60-1	Phenyl glycidyl ether	2b								
60	98-82-8	Cumene	2b								
61	98-83-9	□-Methylstyrene	2b								
62	91-20-3	Naphthalene	2b								
63	78-79-5	Isoprene	2b								
64	106-46-7	para-Dichlorobenzene	2b								
65	98-95-3	Nitrobenzene	2b								
66	1314-62-1	Vanadium pentoxide	2b								
67	117-81-7	Di(2-ethylhexyl)phthalate	2b								
68	140-88-5	Ethyl acrylate	2b								
69	108-10-1	Methyl isobutyl ketone	2b								
70	26471-62-5	Toluene diisocyanates	2b								
71	13463-67-7	Titanium dioxide	2b								
72	1120-71-4	1,3-Propane sultone	2b								
73	151-56-4	Aziridine	2b								
74	18540-29-9	Chromium (VI)	1								
75	15663-27-1	Cisplatin	2a								
76	218-01-9	Chrysene	2b								
77	53-70-3	Dibenz[a,h]anthracene	2a								
78	207-08-9	Benzo[k]fluoranthene	2b								
79		Engine exhaust, gasoline	2b								
80		Wood dust	1								
81	17068-78-9	Asbestos (all forms,	1								
82	14567-73-8	Asbestos (all forms,	1								
83	13768-00-8	Asbestos (all forms,	1								
84	110-00-9	Furan	2b								
85	101-80-4	4,4'-Diaminodiphenyl	2b								
86	75-07-0	Acetaldehyde	2b								
87	100-40-3	4-Vinylcyclohexene	2b								
88	106-88-7	1,2-Epoxybutane	2b								
89	12070-12-1	Cobalt metal with	2a								
90	98-87-3	alpha-Chlorinated	2a								
91	6055-19-2	Cyclophosphamide	1								
92	56-55-3	Benz[a]anthracene	2b								
93	205-99-2	Benzo[b]fluoranthene	2b								
94	205-82-3	Benzo[j]fluoranthene	2b								
95	8007-45-2	Coal-tar distillation	1								
96		Petroleum refining	2a								
97	51-79-6	Ethyl carbamate	2a								
98	106-93-4	Ethylene dibromide	2a								
99	126-72-7	Tris(2,3-dibromopropyl)	2a								
100	56-75-7	Chloramphenicol	2a								

				Database							
				OEL*	REACH, Europe	SIREP, Italy	SUMER, France	EDPB, Belgium	ASA, Finland	CM, Poland	CLP
				Total # of substances present in database:							
	CAS No	Name	Group	106	98	61	53	21	44	82	123
101	119-93-7	3,3'-Dimethylbenzidine (ortho-	2b								
102	72-57-1	Trypan blue	2b								
103	79-46-9	2-Nitropropane	2b								
104	1116-54-7	N-Nitrosodiethanolamine	2b								
105	108-05-4	Vinyl acetate	2b								
106	75-52-5	Nitromethane	2b								
107	111-42-2	Diethanolamine	2b								
108	87-62-7	2,6-Dimethylaniline (2,6-Xylidine)	2b								
109	76-03-9	Trichloroacetic acid	2b								
110	88-72-2	2-Nitrotoluene	2a								
111	91-59-8	2-Naphthylamine	1								
112	92-67-1	4-Aminobiphenyl	1								
113	92-87-5	Benzidine	1								
114	680-31-9	Hexamethylphosphoramide	2b								
115	142844-00-6	Refractory ceramic fibres	2b								
116	189-55-9	Dibenzo[a,i]pyrene	2b								
117	443-48-1	Metronidazole	2b								
118		Mineral oils, untreated or mildly	1								
119		Rubber manufacturing industry	1								
120		Welding fumes	2b								
121	1336-36-3	Polychlorinated biphenyls	1								
122	79-34-5	1,1,2,2-Tetrachloroethane	2b								
123	542-88-1	Bis(chloromethyl)ether;	1								
124	120-80-9	Catechol	2b								
125	84-65-1	Anthraquinone	2b								
126	1309-64-4	Antimony trioxide	2b								
127	10540-29-1	Tamoxifen	1								
128	64742-93-4	Bitumens, occupational exposure	2a								
129	119-61-9	Benzophenone	2b								
130	25013-16-5	Butylated hydroxyanisole (BHA)	2b								
131	126-99-8	Chloroprene	2b								
132	120-71-8	para-Cresidine	2b								
133	693-98-1	2-Methylimidazole	2b								
134	822-36-6	4-Methylimidazole	2b								
135	96-24-2	3-Monochloro-1,2-propanediol	2b								
136	139-13-9	Nitrilotriacetic acid and its salts	2b								
137	116-14-3	Tetrafluoroethylene	2b								
138	86-74-8	Carbazole	2b								
139	68308-34-9	Shale oils	1								
140	98-88-4	alpha-Chlorinated toluenes	2a								
141	75-02-5	Vinyl fluoride	2a								
142	3296-90-0	2,2-Bis(bromomethyl)propane-1,3-	2b								
143	2139594	Potassium bromate	2b								
144	107-30-2	Chloromethyl methyl ether	1								
145	33419-42-0	Etoposide in combination with	1								
146		Soot (as found in occupational	1								
147	23214-92-8	Adriamycin	2a								
148	154-93-8	Bischloroethyl nitrosourea	2a								
149	95-69-2	4-Chloro-ortho-toluidine	2a								
150	70-25-7	*N*-Methyl-*N*´-nitro-*N*-	2a								

				Database							
				OEL*	REACH, Europe	SIREP, Italy	SUMER, France	EDPB, Belgium	ASA, Finland	CM, Poland	CLP
				Total # of substances present in database:							
	CAS No	Name	Group	106	98	61	53	21	44	82	123
151	62-75-9	*N*-Nitrosodimethylamine	2a	not present	not present	not present	not present	not present	not present	present	present
152	8001-58-9	Creosotes	2a	not present	not present	not present	not present	not present	not present	present	present
153	91-94-1	3,3'-Dichlorobenzidine	2b	not present	not present	not present	not present	not present	not present	present	present
154	2475-45-8	Disperse Blue 1	2b	not present	not present	not present	not present	not present	not present	present	present
155	91-23-6	2-Nitroanisole	2b	not present	not present	not present	not present	not present	not present	present	present
156	1836-75-5	Nitrofen (technical-grade)	2b	not present	not present	not present	not present	not present	not present	present	present
157	121-14-2	2,4-Dinitrotoluene	2b	not present	not present	not present	not present	not present	not present	present	present
158	119-90-4	3,3'-Dimethoxybenzidine	2b	not present	not present	not present	not present	not present	not present	present	present
159	97-56-3	ortho-Aminoazotoluene	2b	not present	not present	not present	not present	not present	not present	present	present
160	606-20-2	2,6-Dinitrotoluene	2b	not present	not present	not present	not present	not present	not present	present	present
161	90-94-8	Michler's ketone [4,4′-	2b	not present	not present	not present	not present	not present	not present	present	present
162	193-39-5	Indeno[1,2,3-cd]pyrene	2b	not present	not present	present	not present	not present	not present	not present	not present
163	10026-24-	Cobalt sulfate and other	2b	not present	not present	not present	present	not present	not present	not present	not present
164		Bitumens, occupational	2b	not present	not present	not present	present	not present	not present	not present	not present
165		Engine exhaust, diesel	1	not present	not present	not present	present	not present	not present	not present	not present
166		Aluminium production	1	not present	not present	not present	present	not present	not present	not present	not present
167		Painter (occupational	1	not present	not present	not present	present	not present	not present	not present	not present
168		Dry cleaning (occupational	2b	not present	not present	not present	present	not present	not present	not present	not present
169		MOPP and other combined che	1	not present	not present	not present	present	not present	not present	not present	not present
170		Textile manufacturing	2b	not present	not present	not present	present	not present	not present	not present	not present
171	1746-01-6	2,3,7,8-Tetrachlorodibenzo-	1	not present	not present	not present	not present	not present	present	not present	not present
172	62-50-0	Ethyl methanesulfonate	2b	not present	not present	not present	not present	not present	present	not present	not present
173	66-27-3	Methyl methanesulfonate	2a	not present	not present	not present	not present	not present	present	not present	not present
174	1694-09-3	Benzyl violet 4B	2b	not present	not present	not present	not present	not present	present	not present	present
175	1402-68-2	Aflatoxins	1	not present	not present	not present	not present	not present	present	not present	not present
176	60-35-5	Acetamide	2b	not present	not present	not present	not present	not present	present	not present	present
177	57-74-9	Chlordane	2b	not present	not present	not present	not present	not present	present	not present	present
178	33419-42-	Etoposide	1	not present	not present	not present	not present	not present	not present	present	not present
179	189-64-0	Dibenzo[a,h]pyrene	2b	present	not present	not present	not present	not present	not present	not present	not present
180	446-86-6	Azathioprine	1	present	not present	not present	not present	not present	not present	not present	not present
181	67-72-1	Hexachloroethane	2b	present	not present	not present	not present	not present	not present	not present	not present
182	50-29-3	DDT (4,4'-	2b	present	not present	not present	not present	not present	not present	not present	present
183	62-73-7	Dichlorvos	2b	present	not present	not present	not present	not present	not present	not present	present
184	76-44-8	Heptachlor	2b	present	not present	not present	not present	not present	not present	not present	present
185	509-14-8	Tetranitromethane	2b	present	not present	not present	not present	not present	not present	not present	not present
186	8001-35-2	Toxaphene (Polychlorinated	2b	present	not present	not present	not present	not present	not present	not present	present
187		Isopropyl alcohol	1	present	not present	not present	not present	not present	not present	not present	not present
188		Nickel compounds	1	present	not present	not present	not present	not present	not present	not present	not present
189		Gasoline	2b	present	not present	not present	not present	not present	not present	not present	not present
190		Methylmercury compounds	2b	present	not present	not present	not present	not present	not present	not present	not present
191		Special-purpose fibres such	2b	present	not present	not present	not present	not present	not present	not present	not present
192	15663-27-	Etoposide in combination with	1	present	not present	not present	not present	not present	not present	not present	not present

green	present
red	not present

* OEL (from The Netherlands, Germany, France, Poland, UK or SCOEL)

3 Ranking of the substances, mixtures and processes

3.1 Ranking of the substances

In order to obtain the final short list based on a combination of databases, the substances, mixtures and processes were ranked per database first. It should be noted that, given the large differences between the databases in the number of substances, the method of data collection, data availability per substance, and the type of data collected, no obvious best method for ranking exists (see also Tables 2 and 3). In Annex I, more in-depth descriptions of the respective databases are presented regarding how the data were obtained and the possible limitations of the databases.

The available data do not provide a clear preference for any of the databases. Also, a restriction to one or two databases would not give a result that would be representative for occupational exposure within the EU. In addition, because of the large differences in data collection combining raw data is not meaningful. For these reasons, it was decided to rank substances in the individual databases first and subsequently combined by applying a weighted score. A disadvantage of this approach is that the raw data is no longer directly used and absolute differences in exposed workers within a certain database are lost.

The ranking method was performed as follows. Table 2 shows what exposure indicators are used for ranking the 192 substances that were present in at least one database (Table 3), *i.e.* either on the number of workers exposed, or, in case of the ECHA database, on the number of hits on the preselected PROCs, followed by intended uses and tonnage levels.
Step 1: Based on these criteria, each available substance per database was ranked with the highest value for the ranking variable on top. The substance with the highest rank received a score of 1, the second highest a score of 2, and so on until the last substance for which information is available in that database.
Step 2: All substances that are not present in a specific database, will be given the score of the last substance +1 in that database. For example, the last substance in the EPDB database scores 17. Every other of the 192 substances that is not present will score 18. The underlying thought is that the absence of exposure information in a database is an indication that exposure to that substance is of relatively minor importance for the region covered by the database, for whatever reason.
Step 3: Since the number of substances in the databases varies considerably, the size of the database is corrected by a normalization factor to a scale of 100. Normalization is performed by multiplying the score of a substance in a database by a factor equal to "100/number of substances in that database". For instance, the score of a substance in the Belgian database (17 substances) is multiplied by 5.9 (100/17) while substances in the French database (55 substances) are multiplied by a factor of 1.8 (100/55). Hereby, the scores from the individual databases are equally weighted.

Step 4: The weighted scores per database are summed and divided by the total number of databases, *i.e.* 6. An average weighted score is obtained, which is consequently ranked from the lowest score (highest rank) to the highest score (lowest rank).

Via normalization, in each database, a substance that is absent receives a weighted score of slightly more than 100. In doing so, the scores across the databases are more balanced since they are weighted and normalized. Without adjustment for the number of substances, substances in smaller database will score relatively low (thus ending up high on the ranking). Implicitly, this approach gives additional weight to those substances that are included in more databases, without affecting the relative score of the substance in the individual databases.

The advantage of this approach is that all selected substances/processes are weighted equally and in the same way whether or not a substance is present in a database. As mentioned, this approach favours substances with high occurrence. A disadvantage of this approach is that it implicitly means that the databases are weighted equally, despite differences in data quality. Furthermore, absolute large differences within a certain database are no longer visible in the final ranking, although the underlying ranking in the database is maintained.

3.2 Ranking list

Based on the method described above, the following ranking could be derived (the weighted scores have been rounded). Please note that only the first 30 of 175 substances are presented in Table 5. It is noted that the score only slowly increases with ranking number. For instance, the substance ranked 70 only has a 10-point higher score than the substance ranked 30 (complete ranking list in separate annex (Excel file) to this report).

It may be noted that some relatively well-known substances, mixtures or processes rank high on the list, such as benzene, formaldehyde, acrylamide, and asbestos to randomly name some of those substances. Notably, some substances coming free during processes rank high as well, even though information on processes is present in only two databases. Engine exhaust of gasoline and engine exhaust of diesel (not in top 30) rank relatively high on the total list (Table 5), together with wood dust and petroleum refining. A separate list for processes was generated in view of having information in only two of six databases. In Table 6, 20 processes are ranked in the same way as described in section 3.1, where their rank on the total list is presented as well.

Table 5 Ranking list of substances and processes based on weighted scores for the number of workers exposed per database, together with OELs for the substances, where available[1].

				CLP	OEL	OELs (8-hr TWA) in mg/m3 (unless specified otherwise)						
	CAS No	Name	Weighted score		yes/no	Netherlands	SCOEL	FRANCE	Germany	UK	Poland	Italy
1	71-43-2	Benzene	25			3.25	<3.25	3.25	0.2	3.25	1.6	
2	107-13-1	Acrylonitrile	43				no-oel	4.5	0.26	4.4		
3	50-00-0	Formaldehyde	51			0.15	0.25	0.5 ppm		2.5		
4	106-99-0	1,3-Butadiene	53			46.2	no-oel		0.5	22	4.4	
5	75-01-4	Vinyl chloride	55			7.77	no-oel	2.59		7.8	5	
6	75-21-8	Ethylene oxide	55			0.84	no-oel	1 ppm	0.2	9.2	1	
7	107-06-2	1,2-Dichloroethane	57					40		21	50	
8	106-89-8	Epichlorohydrin	60			0.19	no-oel	10 (15 min; there is no 8hr OEL)	2.3	1.9	1	
9	7440-43-9	Cadmium and cadmium compounds	60				0.004 (respirable fraction)	0.05		0.025	0.01 (inhalable fraction), 0.002 (respirable fraction)	
10	79-06-1	Acrylamide	65			0.16	no-oel	0.3	0.07	0.3	0.1	
11	67-66-3	Chloroform	67			5	10	10		9.9		10
12	7440-02-0	Nickel, metallic and alloys	67				0.005 (respirable fraction), 0.01 (inhalable fraction)	1			0.25	
13	7440-38-2	Arsenic and inorganic arsenic compounds	67			0.025 (water soluble), 0.05 (water insoluble)			0.8 ug/m3	0.1	0.01	
14	14808-60-7	Silica dust, crystalline, in the form of quartz or cristobalite	70			0.075	<0.05	0.1 (quartz)		0.1 (respirable)		
15	302-01-2	Hydrazine	70				no-oel	0.1	2.2 ug/m3	0.03	0.05	
16	7440-41-7	Beryllium and beryllium compounds	70				ongoing	0.002		0.002	0.0002	
17	75-09-2	Dichloromethane (Methylene chloride)	71				353	178		350		
18	218-01-9	Chrysene	71								0.002	
19	108-10-1	Methyl isobutyl ketone	71			104	83	83		208		83
20		Engine exhaust, gasoline	72			240 (if benzene concentration is >0.1%)					500	
21	53-70-3	Dibenz[a,h]anthracene	72								0.004	
22		Wood dust	72			2	0.5 (total dust), 1 (inhalable dust)			5 (hardwood dust), 10 (wood process dust)	4 (except hardwood dusts), 2 (hardwood dusts), 2 (mixture wood dust)	
23	207-08-9	Benzo[k]fluoranthene	73								0.002	
24	1332-21-4	Asbestos	73			*Art. 4.46 arbobesluit			10000 fibres/m3		0.5 (inhalable fraction), 0.1 fibres/cm3 (respirable fraction)	
25	56-55-3	Benz[a]anthracene	73									
26	205-99-2	Benzo[b]fluoranthene	73									
27		Petroleum refining (occupational exposures in)	74									
28	62-55-5	Thioacetamide	75									
29	26471-62-5	Toluene diisocyanates	77					0.08				
30	12001-28-4	Asbestos	77								0.5 (inhalable fraction), 0.1 fibres/cm3 (respirable fraction)	

Table 6 Ranking list of processes and substances without a CAS number only, based on weighted scores for the number of workers exposed per database, together with OELs for the substances, where available.

					OEL	OELs (8-hr TWA) in mg/m3 (unless specified otherwise)			
	Rank on total list	**CAS No**	**Name**	**Weighted score**	**yes/no**	**Netherlands**	**SCOEL**	**UK**	**Poland**
1	**20**		Engine exhaust, gasoline	72		240 (if benzene concentration is >0.1%)			500
2	**22**		Wood dust	73		2	0.5 (total dust), 1 (inhalable dust)	5 (hardwood dust), 10 (wood process dust)	4 (except hardwood dusts), 2 (hardwood dusts), 2 (mixture wood dust)
3	**27**		Petroleum refining (occupational exposures in)	74					
4	**58**		Engine exhaust, diesel	86					
5	**63**		Rubber manufacturing industry	87			ongoing (rubber fumes)	0.6 (rubber fumes), 6 (rubber process dust)	
6	**65**		Refractory ceramic fibres	87					
7	**68**		Welding fumes	87		1			
8	**73**		Soot (as found in occupational exposure of chimney sweeps)	88					
9	**76**		Mineral oils, untreated or mildly treated	88		5	5 (inhalable)		
10	**81**		Aluminium production	90					
11	**82**		Painter (occupational exposure as a)	90					
12	**84**		Dry cleaning (occupational exposures in)	90					
13	**86**		Iron and steel founding (occupational exposure during)	91					
14	**91**		Lead compounds, inorganic	92		*Art. 4.19a arbeidsomstandigheden regeling			
15	**97**		Chlorophenoxy herbicides	92					
16	**100**		Coal gasification	93					
17	**104**		Bitumens, occupational exposure to hard bitumens and their emissions during mastic asphalt work	93					
18	**127**		Methylmercury compounds	96		0.02 (kwik en tweewaardige anorganische kwikverbindingen (gemeten als kwik))			
19	**153**		MOPP and other combined chemotherapy including alkylating agents	100					
20	**158**		Textile manufacturing industry (work in)	100					

4 Discussion and conclusion

In the current project, exposure information on 385 carcinogens was sought from databases across Europe. Information was obtained from databases in France, Poland, Italy, Finland and Belgium, as well as Europe-wide by using the ECHA database. For 175 substances, information was available in one or more of the databases that were consulted. From these databases, exposure related information was used to derive a short list where substances were ranked based on the number of workers exposure or on exposure indicators from the ECHA database.

4.1 Outcome of the ranking

The outcome of the ranking is based on a weighted scoring method, which takes into account the size of the database and assumes equality of the underlying data. Implicitly, this approach favors those substances that occur in most of the 6 different databases and is therefore data driven (or supported by multiple data). As a consequence the approach does not rely on one database, where it follows that a substance with a high ranking in just one database does not automatically end up high on the list. A main disadvantage of this approach is that absolute numbers (raw data) are not used. On the other hand, the limitations regarding the databases refrain from using the raw data and hence ranking based on weighted scores was preferred. As mentioned previously, an obvious method to rank the substances is not possible in light of database differences and data limitations and thus always to some extent arbitrary. There are multiple options depending on what one wishes to emphasize or focus on, but there are no clear criteria to choose the most reliable option.

Benzene, the highest ranking substance on the ranking list, is the only substance occurring in all six databases, which from a historical point of view is not surprising. It is a highly regulated substance across Europe and is monitored quite often, which is caused by cases in the past and the high number of workers potentially exposure to benzene (15). A similar observation can be made for a number of high ranking substances or processes such as formaldehyde, asbestos and engine exhaust of gasoline. Possibly, there is some bias as the well-known substances will be given more attention in monitoring programs, registrations, regulations etc.

It may be noted that the highest ranking substances are generally covered by three or more databases, whereas the top 50 or even top 70 listing substances, by approximation, are generally covered by two or more databases in which a relatively high score was obtained. However, because of the lack of data and limitations of the available data, it is difficult to set a strict ranking order. To take benzene as an example: the substance ranked 48 of 55 in the SUMER survey while ranking 1 of 29, 2 of 18, and 1 of 34 in the SIREP, EPDB and Polish database, respectively. Why benzene did not score high in the SUMER survey cannot be explained; it is noted that approximately 40,000 workers in

France are exposed to benzene indicating that although it scored relatively low in the SUMER database, in absolute sense quite a lot of workers are exposed. A similar observation is made for the other high ranking substances.

4.2 Underlying data and meaning of lack of data

The underlying databases used in this report contain valuable information, but should be considered with care. As has been stressed by several of the database owners, some industries are better represented than others, which may lead to under- or overestimation of exposure to certain substances. Taken together, only an indicative estimation of the most occurring occupational exposure to carcinogens in Europe could be made. It is noted that basically two types of databases are concerned, i.e. those with a legal basis including the country registries and REACH, and the SUMER survey which is based on the assessment of occupational hygienists. As a consequence, there appears to be a bias in the data coverage in the country registries possibly by overrepresentation of certain industrial sectors. As the substances or processes in the SUMER database are often not included in other databases, their ultimate rank is relatively low. Especially concerning processes there is an underreporting of data, causing their rank to be determined predominantly by the SUMER survey. Until more data becomes available, it may be worthwhile to consider processes separately from the substances as it may be anticipated that certain processes are not bound to country specific occupations.

In total, there was no occupational information available for 207 substances, mixtures or processes, which may have various reasons. These substances may not be used, but it could also be due to difficulties in detecting and/or measuring these substances when conducting field surveys. Especially when exposure to a carcinogen is low or the amount used is small, this could hamper their detection, but it may also indicate that the exposure to such substances is of minor importance in that specific country and hence not prioritized for monitoring.

Unfortunately, it was not possible to retrieve information from other European countries, such as the large industrial countries Germany and the United Kingdom or the Eastern European countries besides Poland. It can therefore, not be properly judged to which extent the present results are representative for the EU as a whole. As previously stated by Ter Burg (3), it is recommended to include as many as databases where possible to cover the EU.

4.3 Other exposure indicators

In the current project, only the number of exposed workers was taken into account. Exposure frequency, duration production cycle conditions, or the presence of worker protection were not taken into account. The latter could either be collective protection (such as local exhaust ventilation), or personal protection measurements (such as dermal or respiratory protection). Respiratory protective equipment for example leads to a significant reduction in worker exposure. Information on worker protection was only available in the French SUMER Survey.

Taken together, with the available information, only an indication of the most occurring occupational exposure to carcinogens in Europe could be made.

Other indicators from the SUMER survey, such as intensity and level of exposure were not used, because the intensity of exposure already showed a positive correlation with the number of workers in the SUMER survey and would not change the ranking. The level of exposure is difficult to interpret without having carcinogenic potency data for the substances. It was beyond the scope of this report to retrieve these potency data. Unfortunately, IARC and CLP classifications on carcinogenicity are based on the strength of evidence for the effect rather than on potency.

4.4 Conclusion

It is clear that databases containing information on occupational exposure are very useful in determining the most prevalent carcinogens at the workplace or the carcinogens with the highest number of exposed workers. Unfortunately, not all countries have set up such a database, and in other countries, where a database is available; information is not always accessible due to confidentiality of the data. Moreover, the quality and type of data collected differs per database. By combining data from different countries, corrected for the size of databases and the lack of information, a more complete picture of occupational exposure can be acquired. Even though data may be missing in one country, data from another country can be used to infer exposure to a certain carcinogen. Nevertheless, a clear and concise overview of the most prevalent carcinogens at the workplace in Europe is difficult to obtain.

It may be carefully concluded, considering the available data and associated uncertainties that the top ranking substances will indeed be the most prevalent carcinogens at the workplace in Europe. These substances have relatively high numbers of workers exposed as compared to other substances supported by at least two of the six databases. By using weighted scoring, a list of carcinogens is compiled to which the highest numbers of workers are potentially exposed to in Europe. In addition, a second list is presented where only the processes or substances without a CAS number are included, in order to give these processes more attention as they are generally underreported in databases.

Recommendations to improve insight on prevalent carcinogens at the workplace across Europe could be to create a register on a European level, where information about the number of workers exposed is stored and data are gathered and processed in the same way. It would be highly beneficial if information from all EU Member States could be included, perhaps similar to the CAREX database (6), but by extending the data with information from country specific registries. This report showed that country specific registries contain relevant information. The current CAREX database is outdated and for that reason not considered in this report. There are activities in updating CAREX (likely under a new name) under the auspices of DG Employment. Results are to be expected within 3 years but at this moment no further information is available. It is highly recommended to follow-up on these activities.

Other elements, such as duration of exposure, intensity, and potency of the substance or process may be valuable additions as well as it may lead to a more risk based priority setting of substances or processes. Further, processes and/or substances formed during those processes are currently underreported in the databases, whereas there is common understanding that such processes are important. This was previously underpinned by the consulted experts (3) and the relatively high scoring of processes in the SUMER survey in this report. Additional focus on processes is therefore recommended.

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7 Annex I: Description of the databases

Please note that reference to the excel sheet concerns a separate confidential annex to this report. Other references are taken up in the reference list (Chapter 5.).

In the sections below a description of the databases and the ranking of the substances and processes for the individual databases have been presented (the top 50 or all substance if less than 50 substances included).

7.1 SUMER Survey, France

The medical monitoring survey of professional risks (Surveillance Médicale des Expositions aux Risques professionnels, SUMER) examines working conditions in France. SUMER's main aim is to assess the worker exposure to harmful working conditions and to analyse appropriate protection mechanisms. SUMER is conducted jointly by the general directorate of labour and the directorate for research (DGT), studies and statistics (Dares) of the Ministry of work, employment, vocational training and social dialogue, and co-financed by the general directorate of administration and the public sector. The survey has been carried out in 1994, 2003 and 2010. Compared with earlier editions, the 2010 survey draws on a wider range of employees, most notably from the public sector. For the current project, data of the SUMER survey 2010 were used (7).

The SUMER Survey 2010 consists of interviews with employees conducted by the company medical officer during their regular compulsory medical examination. More than 20% of all medical officers (2400 people) were randomly selected to participate in the survey in 2010. Fieldwork was carried out between January 2009 and April 2010. Medical officers examined 53,940 employees, with 47,983 taking part in the survey. This sample is thought to be representative for the roughly 22 million employees in France. Each questionnaire is assigned a weight (multiplier), so that the occupational exposures of the 48,000 employees represent the total 21.7 million employees in France. A detailed report on the statistics applied to derive the number of workers exposed for each substance is available in French only (8). In total, information is available for 88 substances and/or processes.

From the list of 385 substances, the overlap with the SUMER Survey is 28 substances and 25 processes (53 in total). Ranking was based on the number of employees exposed (Table 7). Other available parameters include the number of workers subdivided per exposure duration, intensity of exposure, protection measures used, or the absence thereof. The number of workers is positively related to the duration or intensity of the exposure, and only minor changes in rank were observed when ranking on either of these parameters.

Table 7 Top 50 substances of SUMER survey based on number of workers exposed.

	CAS No	Name	Group
1		Engine exhaust, diesel	1
2	67-63-0	Isopropyl alcohol manufacture	1
3		Rubber manufacturing industry	
4		Welding fumes	2b
5		Engine exhaust, gasoline	2b
6	108-10-1	Methyl isobutyl ketone	2b
7		Mineral oils, untreated or mildly	1
8		Wood dust	1
9		Rubber manufacturing industry	
10		Petroleum refining	2a
11	14808-60-7	Silica dust, crystalline, in the	1
12	26471-62-5	Toluene diisocyanates	2b
13		Aluminium production	1
14		Painter (occupational exposure	1
15		Dry cleaning (occupational	2b
16	140-88-5	Ethyl acrylate	2b
17		Iron and steel founding	1
18	100-41-4	Ethylbenzene	2b
19	50-00-0	Formaldehyde	1
20		Lead compounds, inorganic	2a
21	7439-92-1	Lead	2b
22		Chlorophenoxy herbicides	2b
23		Coal gasification	1
24		Petroleum refining	
25		Bitumens, occupational	2b
26	8052-42-4	Bitumens, occupational	2b
27	7440-38-2	Arsenic and inorganic arsenic	1
28	106-46-7	*para* -Dichlorobenzene	2b
29	118-74-1	Hexachlorobenzene	2b
30	98-95-3	Nitrobenzene	2b
31	7440-41-7	Beryllium and beryllium	1
32	7440-48-4	Cobalt metal with tungsten carb	2a
33		Methylmercury compounds	2b
34	1314-62-1	Vanadium pentoxide	2b
35	7440-02-0	Nickel, metallic and alloys	2b
36	1332-21-4	Asbestos (all forms, including	1
37		Refractory ceramic fibres	2b
38		Painter (occupational exposure	1
39		Dry cleaning (occupational	2b
40	75-09-2	Dichloromethane (Methylene	2b
41	7440-48-4	Cobalt and cobalt compounds	2b
42	101-14-4	4,4'-Methylenebis(2-	1
43		Rubber manufacturing industry	1
44	101-77-9	4,4'-Methylenedianiline	2b
45	117-81-7	Di(2-ethylhexyl)phthalate	2b
46		MOPP and other combined chei	1
47	7440-43-9	Cadmium and cadmium	1
48	71-43-2	Benzene	1
49		Textile manufacturing industry	2b
50	126-72-7	Tris(2,3-dibromopropyl) phosph	2a

7.2 SIREP database, Italy

The Italian information system for recording occupational exposures to carcinogens (SIREP) was set up in 1996 by the Italian Institute for Occupational Safety and Prevention (ISPESL), as a result of the implementation of European directives concerning the improvement of workplace safety and health. Since 2010, this is now maintained by the National Institute for Insurance against Accident at Work (INAIL). The SIREP database is based on company notifications of the exposed workers. Employers are required to report the carcinogens used, data on exposed employees, and the exposure levels. This information is sent to INAIL every 3 years. SIREP includes quantitative measurements of exposure to airborne carcinogens. It also contains information on the number of exposed workers, but the quality of data differs per substance (i.e. some substances have only a few measurements or only a few exposed workers since not all companies send the required data). The SIREP database contains information on approximately 5000 substances, of which 1500 are linked to exposure measurements, and 600 to airborne concentrations (9).

Information was received for 61 substances. Substances with only a very limited number of measurements (< 50 measurements) were excluded by the data owner since those data were not considered reliable. A total of 126,018 measurements between 1996 and 2013 were selected from the SIREP database for analyses. The results were obtained with automated queries. No judgment was given by experts in occupational hygiene and health on these data. Therefore, some data entry errors could influence the results, especially for substances with limited data. Since only substances with > 50 measurements were considered, this could influence the number of potentially exposed workers for certain economic sectors (e.g. results from small firms may be underreported in this way).
Descriptive statistical analyses were used to calculate the means (arithmetic and geometric) of exposure levels in addition to 95% confidence intervals (CI), standard deviations (SD) and geometric standard deviations (GSD). If for the same substance measurements with different units were found, only the unit of measurement most frequently measured was considered (e.g. FF/L, ppm, mg/m^3 or $\mu g/m^3$). No conversion among units was made.

On a subset of these substances only information on the number of exposed workers is available, on another subset actual measurements are available, and for some substances both endpoints were available. It was stressed by the contact person in charge of the SIREP database that since data collection and reporting is the responsibility of the employer, the quality of the data differs and not all information is considered reliable. Moreover, there are differences in air sampling methods and analytical procedures. The highly variable level of reporting data on registries resulted in a limited estimate of the number of exposed workers in certain economic sectors. The number of exposed workers in each sector was calculated assuming the same ratio between exposed and non-exposed workers in firms reporting and non-reporting exposure data, which may have biased the estimates. To estimate the number of workers potentially exposed, only sectors better represented in the database were taken into account, excluding those with limited information on the size of the reported work force.

Ranking of substances in the SIREP database was done both on the estimated number of exposed workers (29 substances, Table 8) and on the number of measurements (61 substances, not shown). Rather than the actual exposure measurements, the number of measurements was thought to be a better indication as to whether a substance was often used or is of concern. For the final ranking, however, only the number of workers was used since this type of information is also available in other databases.

Table 8 Ranking of the substances in the SIREP database based on the number of workers exposed.

	CAS No	**Description (Italian)**
1	71-43-2	BENZENE
2	12001-29-5	AMIANTO: CRISOTILO
3	7440-02-0	NICHEL METALLICO
4	218-01-9	CRISENE (BENZO[A]PHENANTHRENE)
5	53-70-3	DIBENZO[A,H]ANTRACENE
6	207-08-9	BENZO(K)FLUORANTENE
7	205-99-2	BENZO(E)ACEFENANTRILENE; BENZO(B)F
8	56-55-3	BENZO[A]ANTRACENE
9	107-13-1	ACRILONITRILE
10	302-01-2	IDRAZINA
11	107-06-2	1,2-DICLOROETANO
12	50-00-0	FORMALDEHYDE (FORMALDEIDE)
13	106-89-8	1 CLORORO-2,3-EPOSSIPROPANO; EPICLOI
14	106-99-0	1,3-BUTADIENE
15	75-01-4	CLOROETILENE; VINILE CLORURO (VCM;
16	75-21-8	OSSIDO DI ETILENE
17	100-44-7	CLORURO DI BENZILE; ALFA-CLOROTOLU
18	1332-21-4	ASBESTOS
19	12001-28-4	AMIANTO: CROCIDOLITE
20	62-55-5	TIOACETAMMIDE
21	78-79-5	ISOPRENE
22	14808-60-7	SILICA CRYSTALLINE (QUARTZ); SILICE C
23	77-78-1	DIMETILSOLFATO
24	67-66-3	CHLOROFORM (CLOROFORMIO; TRICLOR
25	75-09-2	DICHLOROMETHANE (METHYLENE CHLO
26	95-53-4	O-TOLUIDINA (ORTO-TOLUIDINA)
27	15663-27-1	CISPLATIN (CISPLATINO)
28	12172-73-5	AMIANTO: AMOSITE
29	6055-19-2	CYCLOPHOSPHAMIDE MONOHYDRATE

7.3 EDPB database, Belgium

The EDPB ("Externe Diensten voor Preventie en Bescherming op het werk") consists of two departments: risk management and medical supervision. Every EDPB represents 1000 to several 10,000 firms. In total, there are thirteen EDPBs, representing 210,000 enterprises and approximately 3.3 million workers, which is approximately 90% of the total workforce. Self-employed workers are not included in the EDPB; the ratio "employees to self-employed workers" is thought to be approximately 5:1. Each year, every EDPB needs to send in a report detailing the number of workers that has been exposed to a subset of specific substances (e.g. benzene, asbestos), but more often to a grouped set of substances (e.g. chrome and inorganic compounds). These can be carcinogenic, but not necessarily. As such, many of the 385 substances from the list cannot be traced individually, but will be grouped. Unfortunately, it turned out that retrieving information on the grouped substances was not possible. Therefore information on a mere 17 substances was available.

Information was obtained on the number of exposed workers, the percentage of exposed workers, and the corrected number of workers based on the total Belgian workforce. The substances were ranked on the number of exposed workers (Table 9). The information received concerns information on exposed workers in 2013, except for EDPB13, for which only data are available over 2012. The reliability of the data provided by each EDPB was not checked. The EDPBs provide information on about 90% of the Belgian workforce. It should be stressed that enterprises can be over-represented in one EDPB, while under-represented in the other. As a result, data entry errors could over- or underestimate exposure in certain economic sectors.

Table 9 Ranking of the substances in the EDPB database based on number of workers exposed.

	CAS No	Name
1	1332-21-4	Asbestos (all forms,
2	71-43-2	Benzene
3	14808-60-7	Silica dust,
4	50-00-0	Formaldehyde
5	7440-43-9	Cadmium and
6	7440-38-2	Arsenic and
7	75-09-2	Dichloromethane
8	107-13-1	Acrylonitrile
9	127-18-4	Tetrachloroethylene
10	75-01-4	Vinyl chloride
11	67-66-3	Chloroform
12	13463-67-7	Titanium dioxide
13	98-82-8	Cumene
14	1333-86-4	Carbon black
15	7440-41-7	Beryllium and
16	75-21-8	Ethylene oxide
17	56-23-5	Carbon tetrachloride

7.4 Central register of Carcinogenic or Mutagenic agents (CM register), Poland

The central register of exposure to carcinogenic and/or mutagenic substances, preparations or technological processes is compiled at the Nofer Institute of Occupational Medicine (NIOM), which was established in 1954. The register contains information received from all provinces in Poland on the basis of data from employers. Since 1999, data are reported to the sanitary inspection yearly, which transfers the data to the register. Information is available about the number of enterprises and the total number of exposed people. Data about the duration and level of exposure are also available, but only for those substances with established OELs in Poland. For this project, information was received on the number of exposed workers in 2013 for 78 substances and 4 processes (see Table 10 where the top 50 substances are presented).

Table 10 Ranking of the Top 50 substances in the Polish registry based on the number of workers exposed the number of workers exposed.

	CAS No	Name
1	56-55-3	Benz[a]anthracene
2	218-01-9	Chrysene
3	207-08-9	Benzo[k]fluoranthene
4	205-99-2	Benzo[b]fluoranthene
5	53-70-3	Dibenz[a,h]anthracene
6		Wood dust
7	71-43-2	Benzene
8		Engine exhaust, gasoline
9		Soot (as found in
10		Petroleum refining
11	7440-38-2	Arsenic and inorganic arsenic
12	79-06-1	Acrylamide
13	75-21-8	Ethylene oxide
14	7440-43-9	Cadmium and cadmium
15	75-01-4	Vinyl chloride
16	12001-28-4	Asbestos (all forms, including
17	107-06-2	1,2-Dichloroethane
18	302-01-2	Hydrazine
19	62-55-5	Thioacetamide
20	77-09-8	Phenolphthalein
21	107-13-1	Acrylonitrile
22	18540-29-9	Chromium (VI) compounds
23	106-99-0	1,3-Butadiene
24	92-87-5	Benzidine
25	569-61-9	CI Basic Red 9
26	106-89-8	Epichlorohydrin
27	119-90-4	3,3'-Dimethoxybenzidine
28	77-78-1	Dimethyl sulfate
29	100-44-7	alpha-Chlorinated toluenes
30	95-53-4	ortho-Toluidine
31	106-47-8	para-Chloroaniline
32	119-93-7	3,3'-Dimethylbenzidine (ortho-
33	106-93-4	Ethylene dibromide
34	142844-00-6	Refractory ceramic fibres
35	7440-41-7	Beryllium and beryllium
36	7440-43-9	Cadmium and cadmium
37	50-18-	Cyclophosphamide /
38	556-52-5	Glycidol
39	91-23-6	2-Nitroanisole
40	64-67-5	Diethyl sulfate
41	95-69-2	4-Chloro-ortho-toluidine
42	15663-27-1	Cisplatin
43	33419-42-0	Etoposide in combination
44	23214-92-8	Adriamycin
45	118-74-1	Hexachlorobenzene
46	91-59-8	2-Naphthylamine
47	121-14-2	2,4-Dinitrotoluene
48	8007-45-2	Coal-tar distillation
49	205-82-3	Benzo[j]fluoranthene
50	90-04-0	ortho-Anisidine

7.5 ASA Database, Finland

In 1977, the International Labour Office (ILO) recommended recording systems for the monitoring of occupational exposure to carcinogens. This resulted in the Finnish Register of Employees Exposed to Carcinogens (ASA database) in 1979. Employers are obliged to provide data on the use of carcinogens and to notify exposed workers to the labour safety authorities annually (since 2006 to the Finnish Institute of Occupational Health (FIOH)). Only the number of exposed workers is registered, no information on the level of exposure is available. During 1979 and 2010, nearly 117,000 workers from 4300 workplaces were recorded. The ASA database is based on an administrative list of carcinogens compiled by the Finnish Ministry of Social Affairs and Health. The list contains information on 169 substances and 5 processes; of these, there are 27 substances for which no exposure has been reported. Although registration is obligatory, it is probable that temporary and low exposures, as well as exposures in small workplaces are not fully covered (10).

Information was received on 44 substances; nobody had been exposed to 10 of these substances. Information is available on the total number of exposed workers in 2013, since the 2014 exposure information is not yet available. See Table 11 where the substances have been ranked based on the number of workers exposed.

Table 11 Ranking of substances in ASA database based on number of workers exposed workers exposed exposed workers exposed.

	CAS No	Name
1	71-43-2	Benzene
2	50-18-0	Cyclophosphamide
3	67-66-3	Chloroform
4	79-06-1	Acrylamide
5	106-99-0	1,3-Butadiene
6	1336-36-3	Polychlorinated biphenyls
7	72-57-1	Trypan blue
8	106-89-8	Epichlorohydrin
9	107-13-1	Acrylonitrile
10	569-61-9	CI Basic Red 9
11	107-06-2	1,2-Dichloroethane
12	75-21-8	Ethylene oxide
13	79-34-5	1,1,2,2-Tetrachloroethane
14	60-35-5	Acetamide
15	123-91-1	1,4-Dioxane
16	56-23-5	Carbon tetrachloride
17	75-01-4	Vinyl chloride
18	95-80-7	2,4-Diaminotoluene
19	64-67-5	Diethyl sulfate
20	106-93-4	Ethylene dibromide
21	62-55-5	Thioacetamide
22	1402-68-2	Aflatoxins
23	1746-01-6	2,3,7,8-
24	118-74-1	Hexachlorobenzene
25	57-74-9	Chlordane
26	51-79-6	Ethyl carbamate
27	101-77-9	4,4'-Methylenedianiline
28	96-09-3	Styrene-7,8-oxide
29	62-50-0	Ethyl methanesulfonate
30	838-88-0	4,4'-Methylene bis(2-
31	77-78-1	Dimethyl sulfate
32	151-56-4	Aziridine
33	60-09-3	para-Aminoazobenzene
34	66-27-3	Methyl methanesulfonate
35	96-23-1	1,3-Dichloro-2-propanol
36	1120-71-4	1,3-Propane sultone
37	75-55-8	2-Methylaziridine
38	98-07-7	alpha-Chlorinated
39	98-87-3	alpha-Chlorinated
40	1694-09-3	Benzyl violet 4B
41	542-88-1	Bis(chloromethyl)ether;
42	79-44-7	Dimethylcarbamoyl
43	126-72-7	Tris(2,3-dibromopropyl)
44	593-60-2	Vinyl bromide

7.6 ECHA database, Europe

The ECHA database consists of substances that are registered under REACH. Currently, all substances produced, manufactured, or imported over 100 tons per annum (t.p.a.) in Europe must be registered with the European Chemicals Agency (ECHA). Substances produced, manufactured, or imported over 1 t.p.a., but below 100 t.p.a. need to be registered by 2018. However, carcinogenic, mutagenic or reprotoxic (CMR) substances categories 1A and 1B > 1 t.p.a. have to be registered already. As can be seen in Excel sheet (1), not all category 1 carcinogens are registered under REACH, indicating that they are not used (anymore), the tonnage is below 1 t.p.a., or the registrant did not fulfill the registration requirements. Finally, category 2 carcinogens with a tonnage band between 1 and 100 t.p.a. do not require registration yet, and thus information on these substances could not be obtained, unless a registration file was available. In total, 8269 substances are currently registered under REACH (11, 12); information is available for 98 substances from the list of 385 carcinogens.

Information requirements under REACH are set out in the Annexes VI to XI of REACH (13). There are 2 types of registration; full registration and intermediate registration (isolated intermediate conform art. 3 of REACH). For these 2, there is a difference in information requirements. Generally speaking there are no information requirements for intermediates under REACH. 23 of the 98 substances registered under REACH are registered as an intermediate, and 1 of the substances is registered for both.

The information registrants have to provide for a full registration is automatically searchable in the ECHA database. Regarding exposure, the information is at a relatively high abstraction level. The registrant is obliged to include a brief general description of all identified uses, covering the entire life cycle of the substance. For each identified use, a further description of use and/or exposure is required. For this, ECHA has developed the Use Descriptor System (UDS) (14). There are five separate descriptors that aim to give an overview in which sector and product category the substance is used, which application techniques or processes are utilized, whether it is processed into an article, and whether the substance is released into the environment. For each of these descriptors, standardized categories have been developed. The combination of categories selected from each of the descriptor lists results in a brief description of the use of the registered substance.
The five separate descriptors are:

1. Sector of use (SU): describes in which sector the substance is used, with the main categories being industrial, consumer and/or professional.
2. Process Category (PROC): describes the application techniques or process types defined from an occupational perspective. As such, it is the prime determinant for the level of occupational exposure.
3. Product Category (PC): describes the types of chemical products in which a substance is used, and thus gives information on potential professional and consumer exposure. Registrants do no

need to disclose information who (professionals, consumers or both) is using the product.

4. Article Category (AC): describes the type of article in which the substance has been processed.
5. Environmental Release Category (ERC): describes the broad conditions of use from an environmental perspective, based on those characteristics that give a first indication of the potential release of the substance to the environment.

For the current project, those categories were selected that are expected to have high occupational exposure potential, and these were used in subsequent ranking steps. The criteria are total number of identified uses (indicative of widespread use), the process activities (PROCs) known to have high exposure potential, and total tonnage levels. For the process activities, a subset of 12 PROCs was selected that, according to the worker exposure screening tool ECETOC TRA V3.1 Worker module, give the highest potential exposure. No information on the tonnage level was available for 3 substances, after manually checking these on the ECHA website, they turned out to be registered as intermediates. In general, there is no further information available for substances registered as intermediate; only 2 intermediate substances had information on either PROCs or identified uses.

As mentioned, 98 of the 385 substances are registered under REACH. For 59 of these substances, at least one positive hit was found for the PROC criterion. If there were no hits on the selected PROCs, substances were ranked according to the total number of identified uses and subsequently by tonnage level (see Table 12). If substances only have information on tonnage level, but are lacking information on PROCs and identified uses, this could be because they are used under controlled conditions that do not result in worker exposure. However, it could also be due to confidentiality, or the information requirements were not fulfilled. In the latter 2 cases, they may be wrongly ranked in the lower portion of the list. To exclude this possibility, manual screening of the individual substances is required. Next to checking the registration file, this could entail contacting the registrant to get further information on the use of the substance. This was beyond the scope of the current project. Intermediates are ranked last, since these substances are used under strictly controlled conditions and therefore only result in no, or only very limited worker exposure.

The data show that the number of identified uses and the number of PROCs are correlated, but any combination with tonnage level shows a more scattered picture. As such, a high tonnage level is not a very good predictor of the exposure potential; however, a low tonnage level generally does show a low number of uses and a low number of PROCs. In conclusion, only small changes in rank are observed between substances that are ranked on PROCs vs. ranking on identified uses.

Table 12 Ranking of substances in ECHA database based on the number of PROCs per substance and subsequent number of identified uses and tonnage levels.

	CAS No.	Name
1	13463-67-7	Titanium dioxide
2	1309-64-4	Antimony trioxide
3	1333-86-4	Carbon black
4	108-10-1	Methyl isobutyl ketone
5	50-00-0	Formaldehyde
6	139-13-9	Nitrilotriacetic acid and its
7	64742-93-4	Bitumens, occupational
8	8052-42-4	Bitumens, occupational
9	12070-12-1	Cobalt metal with tungsten
10	119-61-9	Benzophenone
11	111-42-2	Diethanolamine
12	100-42-5	Styrene
13	7440-48-4	Cobalt metal with tungsten
14	7440-48-4	Cobalt and cobalt compounds
15	7440-48-4	Cobalt metal without tungsten
16	65996-93-2	Coal-tar pitch
17	78-79-5	Isoprene
18	7440-02-0	Nickel, metallic and alloys
19	98-82-8	Cumene
20	75-09-2	Dichloromethane (Methylene
21	106-99-0	1,3-Butadiene
22	1314-62-1	Vanadium pentoxide
23	7440-43-9	Cadmium and cadmium
24	26471-62-5	Toluene diisocyanates
25	7439-92-1	Lead
26	117-81-7	Di(2-ethylhexyl)phthalate
27	107-13-1	Acrylonitrile
28	127-18-4	Tetrachloroethylene
29	7440-41-7	Beryllium and beryllium
30	75-21-8	Ethylene oxide
31	123-91-1	1,4-Dioxane
32	108-05-4	Vinyl acetate
33	693-98-1	2-Methylimidazole
34	71-43-2	Benzene
35	98-83-9	□-Methylstyrene
36	140-88-5	Ethyl acrylate
37	25013-16-5	Butylated hydroxyanisole
38	75-52-5	Nitromethane
39	76-03-9	Trichloroacetic acid
40	106-46-7	*para*-Dichlorobenzene
41	67-66-3	Chloroform
42	84-65-1	Anthraquinone
43	100-41-4	Ethylbenzene
44	91-20-3	Naphthalene
45	98-95-3	Nitrobenzene
46	107-06-2	1,2-Dichloroethane
47	75-01-4	Vinyl chloride
48	101-14-4	4,4'-Methylenebis(2-
49	96-09-3	Styrene-7,8-oxide
50	106-89-8	Epichlorohydrin

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