European Agency for Safety and Health at Work

Developing a data-driven method for assessing and monitoring exposure to dangerous substances in EU workplaces

European Risk Observatory
Summary

European Agency for Safety and Health at Work

Safety and health at work is everyone's concern. It's good for you. It's good for business.

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1 Dangerous substances at work

A 'dangerous substance' is any substance (liquid, gas or solid) that can be harmful to humans' health or safety. Dangerous substances can be found in almost every workplace and, across Europe, millions of workers come into contact with chemical and biological agents that can harm them.

Workers can be exposed to dangerous substances through all three routes of exposure (inhalation, dermal, ingestion) and they may not be adequately informed about their presence in the workplace, the potential threats arising from exposure to them and appropriate methods to prevent or control exposure. In the EU, dangerous substances are classified based on categories defined in Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures (known as the Classification, Labelling and Packaging (CLP) Regulation). These include physical hazards (explosive, flammable, unstable, etc.); health hazards (all aspects of short- and long-term harm to health); and environmental hazards (aquatic environments, etc.).

Many misconceptions adopted by workers and employers can lead them to falsely believe that exposure to dangerous substances is irrelevant to them and that no action is needed to prevent exposure, especially where the effects are slow acting. Exposure to dangerous substances can be found in many different situations, but may not be apparent to someone without the proper skills or knowledge to judge the situation. There is also a misconception that the use of dangerous substances has decreased in general, which, in recent years, is true for some of the more notorious substances (e.g. asbestos, lead, mercury) but not for many other, less well-known substances. In addition, dangerous substances are often mistakenly perceived as being only chemicals that are 'man-made', often with a strong smell or apparent acute dangerous effects (https://healthy-workplaces.eu/en/campaign-materials/campaign-guide EU-OSHA, 2018).

These are core issues that the new Healthy Workplaces Campaign of the European Agency for Safety and Health at Work (EU-OHSA) addresses. The 2018-19 campaign, entitled 'Healthy Workplaces Manage Dangerous Substances', aims to improve access to and awareness of the most relevant and widely applicable practical solutions and guidance, as well as disseminate examples of good practice.

To support the campaign, EU-OSHA commissioned and carried out a broad range of activities, including a research study carried out by the Institute of Occupational Medicine on which this summary report is based. The study aimed to inform EU-OSHA's campaign by:

i. providing it with a quantitative and qualitative overview of the use of dangerous substances within European workplaces;

ii. developing and piloting a scientifically based methodology that could, in future, provide a basis for monitoring trends and developments in the production of, the use of and exposure to dangerous substances.

2 Objectives

Specific objectives addressed by the project included the following:

- for workers within European workplaces, identify the dangerous substances and related industrial sectors that are of greatest concern;
- develop a short list of the most important industries and dangerous substances within European workplaces and, from it, select and analyse those in need of more detailed evaluation to identify trends in use and exposure;
- for a limited number of dangerous substances from the short list, examine trends over time in the quantities manufactured and used, and in the levels of exposure;
- develop a scientific method that can be used as a prototype for such data-driven work in similar exercises in the future.

This report presents a summary of the methods developed and the results arising from the pursuit of these objectives.

Those looking for more details on the research are referred to the original project's comprehensive technical report, produced as part of the work and available online at: https://oshwiki.eu/wiki/Developing_a_datadriven_method_for_assessing_and_monitoring_exposure_to_dangerous_substances_in_EU_workplaces. The technical report regarding the research presents the aims and objectives, methodology, results and discussion in much greater detail, including extensive annexes.

3 How did we go about meeting our objectives?

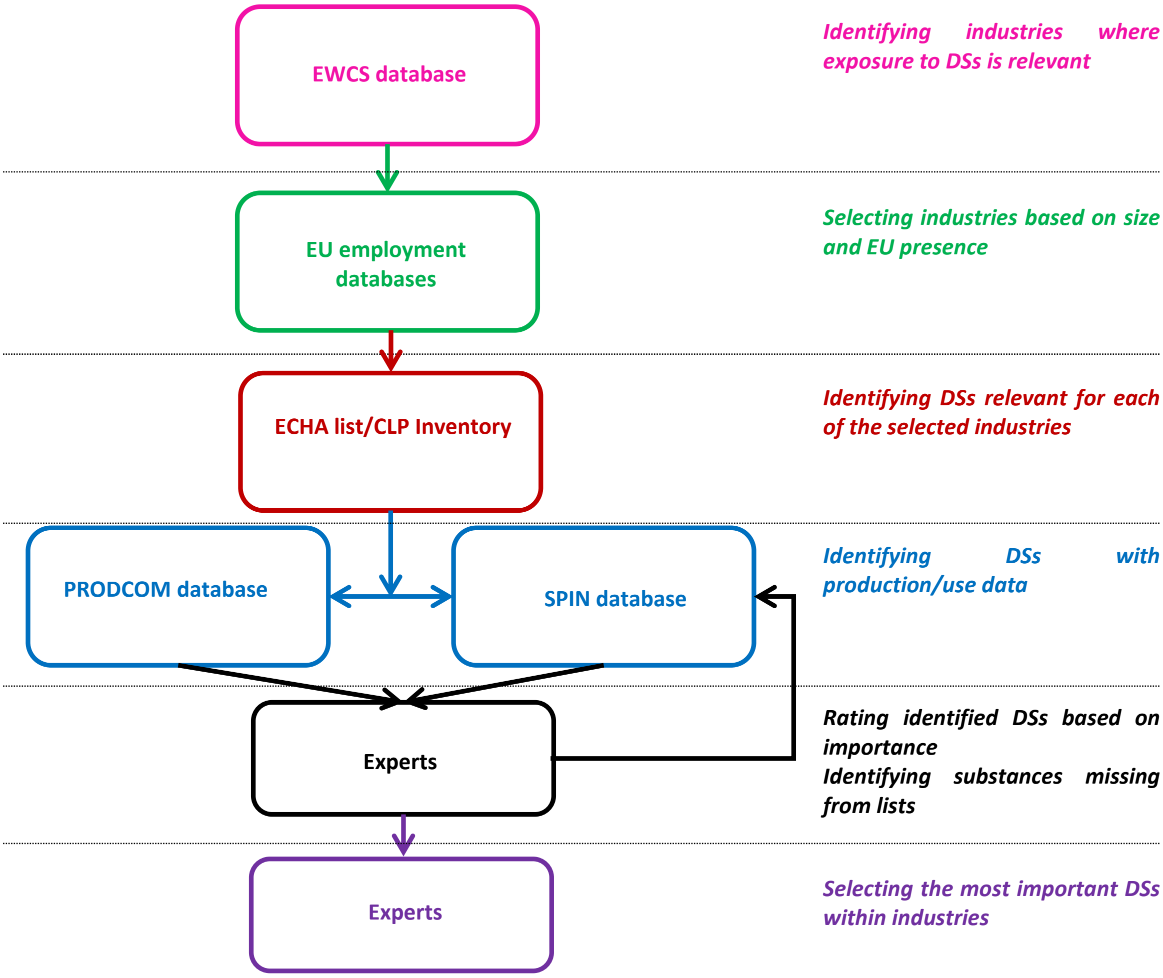
Firstly, datasets related to employment statistics, chemical manufacturing and use, as well as the trade or production of goods (Table 1) were collected from several publicly available EU sources. Then, using the in-depth knowledge and insight of experts in chemical risk assessment and industrial hygiene (IH) in the EU, the data were collated and linked or merged in several ways, to allow further sub-selection and analysis.

Table 1. An overview of the publicly available data sources used by the project

The European Working Conditions Survey (EWCS)[1] The EWCS is an EU-wide questionnaire survey on working conditions performed at five-year intervals. It addresses issues related to employment status and conditions, working characteristics, quality of life and health. In its latest round, 44,000 workers across 35 countries participated in the survey.
EU employment databases EU Member States regularly perform systematic labour market surveys, typically covering business demographics, outputs (e.g. turnover, value added) and inputs (e.g. labour characteristics, characteristics of goods and services), and capital input (e.g. material investments). These mostly cover certain industries and their results are managed by EUROSTAT. For the present work, data from structural business statistics (SBS)[2], the Joint Forest Sector Questionnaire (JFSQ)[3] and the EU Labour Force Survey (EU LFS)[4] were employed in particular.
The list of registered substances/Classification, Labelling and Packaging C&L Inventory[5] The list of registered substances contains data from the registration dossiers submitted to the European Chemicals Agency (ECHA), including information on several substance-related data, such as hazardous properties, the classification and labelling of substances in accordance with the CLP Regulation and their safe use. It offers a web-based interface and search engine.
The Substances in Preparations in Nordic Countries (SPIN) database[6] The SPIN database contains non-confidential information regarding the basic attributes of chemical substances (e.g. names, standardised unique identifiers) and downstream use characteristics (e.g. industrial use category, annual tonnage) for Denmark, Finland, Norway and Sweden.
The Production of Manufactured Goods (PRODCOM) database[7] The PRODCOM database compiles annual national survey statistics on the production of manufactured goods within European countries. Available information includes information on the physical volume of production sold during the survey period, the value of production sold during the survey period and, for some products, the volume of the total production during the survey period.

[1] http://www.eurofound.europa.eu/surveys/european-working-conditions-surveys/fifth-european-working-conditions-survey-2010
[2] http://ec.europa.eu/eurostat/web/structural-business-statistics
[3] http://ec.europa.eu/eurostat/web/forestry/overview
[4] http://ec.europa.eu/eurostat/web/microdata/european-union-labour-force-survey
[5] 'Advanced search' in https://echa.europa.eu/home
[6] http://spin2000.net/
[7] https://ec.europa.eu/eurostat/web/prodcom

Figure 1: Schematic representation of the project's working strategy



Notes: EWCS = European Working Conditions Survey; DSs = dangerous substance; ECHA = European Chemicals Agency; CLP = Classification, Labelling and Packaging; PRODCOM = Production of Manufactured Goods; SPIN = Substances in

A schematic representation of the overall working strategy applied in the project is shown in Figure 1. The process adopted was essentially a tiered filtering and selection process of a combination of information from the databases, with the judicious application of expert knowledge to refine the process at each stage in an iterative manner. The data extracted by the project to develop and test the prototype methodology were retrieved from their sources as needed between February and May 2017.

Initially, industries where exposure to dangerous substances is potentially an issue were identified by analysing the 2015 EWCS data, using information self-reported by workers regarding their potential exposure to dangerous substances at work. A stratified analysis by industry was performed using the EU standard industry classification system (NACE)[8] to group results. Those industries where more than 30% of the workers participating in the EWCS reported exposure to smoke, fumes, powder, dust, vapours, tobacco, chemicals and infectious materials, either through direct contact (e.g. skin) or breathing, for at least 25% of their working time were selected for further analysis.

These results were then combined with corresponding EU employment databases to evaluate the size and representativeness of the industries identified at an EU level. Only industries with a) a presence in more than half of the EU-28 countries and b) an overall EU workforce exceeding 100,000 persons were

[8] https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF

then retained for further analysis. Industries recognised as being in systemic decline within the EU (i.e. coal mining) or heavily regulated and controlled (e.g. pharmaceuticals) were eliminated from the list.

Dangerous substances relevant to each of the industries were then identified by way of their hazard attributes (carcinogenicity, mutagenicity, toxicity to reproduction, sensitisation ability and environmental toxicity), as registered in the ECHA CLP Inventory[9], and appropriate data were extracted for each. Data extraction was performed at an industry sector level by employing the 'Sectors of Use (SU)' classification[10] used within the REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) list. The dangerous substances identified were then combined with the usage statistics per substance in Nordic countries, as detailed in the SPIN database. Unique substance identifiers (CAS numbers) were used to match and merge data from the two databases.

For each dangerous substance selected by the previous steps, patterns of use and representativeness across the industries identified and the four Nordic countries present in the SPIN database were assessed. A substance not used by a related industry in at least three of the four Nordic countries, and with total amounts of use of less than 100 kg, was eliminated. However, for some industries, substances were low in numbers or, according to SPIN, used in minimal quantities. For these industries, the above criteria were necessarily relaxed.

At this stage, it was recognised that there was the chance that some substances or industry combinations may have been omitted because of some limitations in the characteristics of the contributing databases. Therefore, the list of remaining substances for every industry was closely scrutinised by experts in chemical risk and industrial hygiene, to identify any dangerous substances that were clearly missing. Following the screening process, in-use volumes for all substances occurring during the period 2008 to 2015 were extracted and analysed for time trends. In addition to SPIN data, production data on manufactured amounts, where available, were also extracted from the PRODCOM database for analysis.

To further evaluate the results at this point, a two-way table was made, arranging the remaining candidate substances by industry. The experts then rated the importance of each item in the matrix, using a clear and simple three-point scale (low to high) for each of the following three factors:

a) the number of workers currently potentially exposed to the substance within the given industry;
b) the likelihood of exposure occurring while working with the substance within the given industry;
c) the potential impact of exposure on the health, working life and social life of the worker.

The allocated scores were then added together to give an overall score of relevance for each substance, with values ranging between three and nine for each cell in the matrix. Where results differed between experts, examination, arbitration and a final result were provided by an additional independent expert, who assessed each cell in question. The overall score then identified the most important industry and substance combinations, where a score of six or more (≥6) led to the substance being included in further analysis and reporting in a standardised 'Dangerous Substance Data Summary' information sheet. This described key facts about the substance, including data on the identification, labelling and classification of the substance, its industry relevance and related trends, and characteristics in employment, use and production volumes, with some comments and observations.

4 What were the results of the analysis?

4.1 General overview

Figure 2 provides an overview, with the number of records at each stage of the process, of the procedure applied to identify and select the most important dangerous substances and related industries where exposure to dangerous substances is possible.

Of the 99 NACE-coded industries included in the 2015 EWCS results, 33 industries were identified as ones where exposure to dangerous substances may be a highly important issue for workers. However,

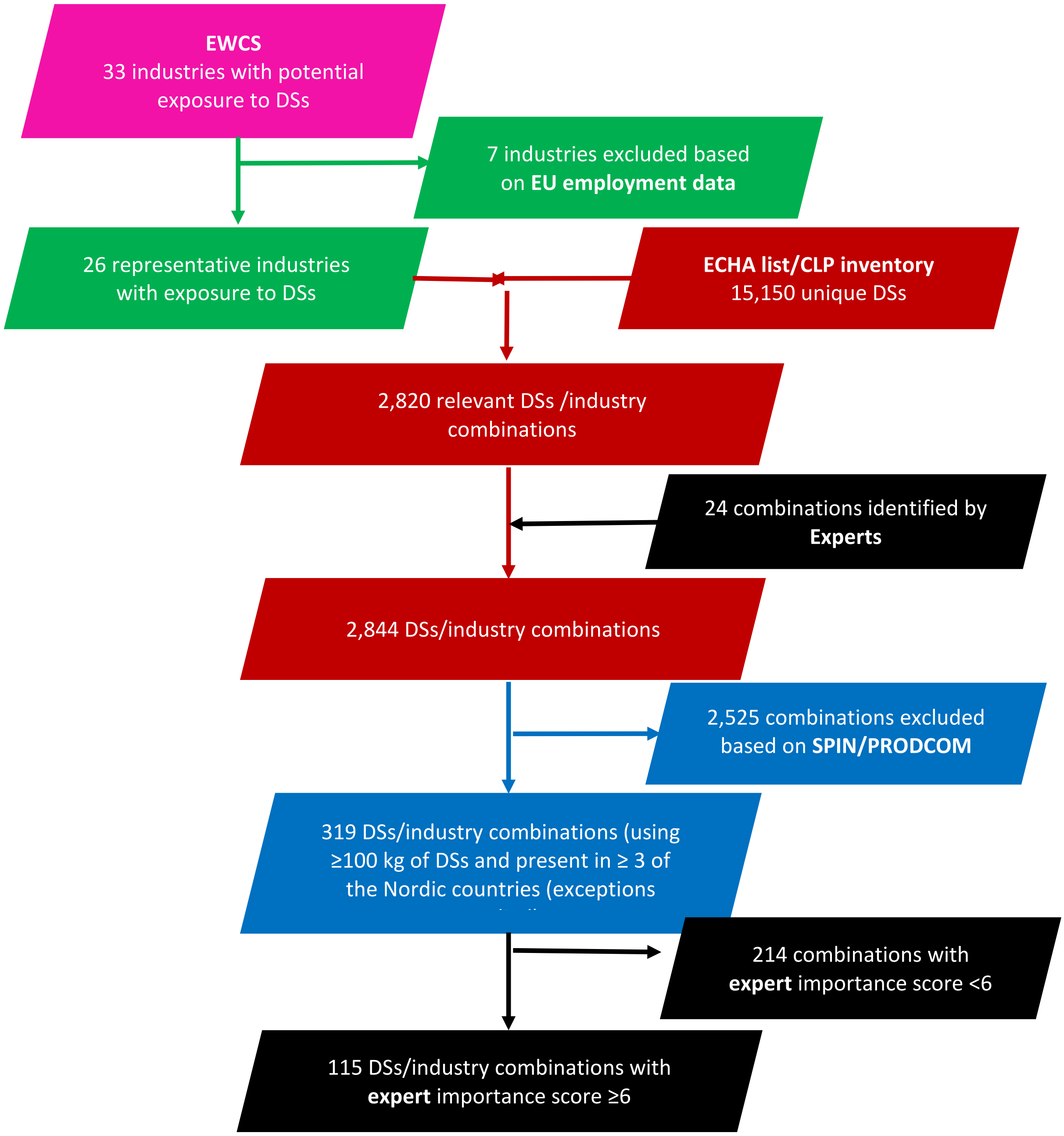
[9] https://echa.europa.eu/regulations/clp/understanding-clp
[10] https://echa.europa.eu/documents/10162/13632/information_requirements_r12_en.pdf

of these, only 26 fulfilled the criteria requiring industries to be representative at a cross-EU level and with a sizeable workforce.

A list of 15,150 unique dangerous substances relevant to these 26 industries was extracted from the ECHA substance C&P Inventory, which, when merged with the SPIN data, resulted in 2,820 relevant combinations of industries and substances with suitable usage data available. This list was supplemented with a further 24 combinations, identified by the experts as significant omissions at that stage, giving 2,844 combinations for further evaluation.

Of the 2,844 combinations assessed, 319 combinations satisfied the criteria for the use of the dangerous substance in amounts exceeding 100 kg across all the Nordic countries that provided data for the specific industry. There were 142 unique substances in the 319 industry-substance combinations, in one or more of the 26 industries. The experts then evaluated and scored the importance of each of these 319 combinations.

Figure 2: Flow chart describing the relevant dangerous substance (DSs) and industry identification and selection process



A score of six or higher was given by the experts to 115 of the industry-substance combinations assessed, representing 68 unique substances used in one or more of the industries. This reflected the 48% of the 142 unique substances meeting the selection criteria and included in the experts' evaluations. A 'Dangerous Substance Data Summary Sheet' was then developed for each of the 68 substances, using the results of their preceding analysis, supplemented with additional information on their characteristics retrieved from the cited data sources. An example of a 'Dangerous Substance Data Summary Sheet' for toluene is illustrated in Annex 1. The analysis results are discussed in greater detail below.

4.2 Industries with exposure to dangerous substances

As noted above, the process of identifying industries where exposure to dangerous substances is an issue began with the analysis of self-reported exposure data from the EWCS. This analysis was based on industry codes (as defined by NACE) and a list of those industries (and codes) that fulfilled selection criteria regarding proportions of positive responses on exposure, size (in terms of workforce) and representativeness across EU countries is shown in Table 2. In terms of substance categories, exposure to smoke, fumes, powder and dust appeared to be most common, with workers in more than 17 (65%) of these industries reporting exposure to these substances as an issue, whereas exposure to chemicals through direct handling or skin contact was prevalent in 11 (42%) of these industries. Exposure to vapours from solvents and infectious agents was far less common, with the prevalence of reported exposure exceeding 30% in fewer than five of the industries included in both cases. An overview of the distribution of self-reported exposure provided in the EWCS across these industries is shown in Figure 3. Figure 4 summarises these estimates as a function of the estimated EU workforce for each of these industries.

Table 2. Industries with workforces above 100,000 persons and a presence in more than half EU-28 countries, where more than 30% of participating workers in the EWCS reported potential exposure to dangerous substances for more than 25% of their working time

Industry name (as defined by NACE)	NACE v2.2 code	Industry name (as defined by NACE)	NACE v2.2 code
Forestry and logging	A02	Manufacture of furniture	C31
Other mining and quarrying	B08	Repair and installation of machinery and equipment	C33
Manufacture of leather and related products	C15	Waste collection, treatment and disposal activities; materials recovery	E38
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	C16	Construction of buildings	F41
Printing and reproduction of recorded media	C18	Civil engineering	F42
Manufacture of coke and refined petroleum products	C19	Specialised construction activities	F43

Industry name (as defined by NACE)	NACE v2.2 code	Industry name (as defined by NACE)	NACE v2.2 code
Manufacture of chemicals and chemical products	C20	Wholesale and retail trade and repair of motor vehicles and motorcycles	G45
Manufacture of rubber and plastic products	C22	Water transport	H50
Manufacture of other non-metallic mineral products	C23	Veterinary activities	M75
Manufacture of basic metals	C24	Services to buildings and landscape activities	N81
Manufacture of fabricated metal products, except machinery and equipment	C25	Human health activities	Q86
Manufacture of machinery and equipment n.e.c.	C28	Residential care activities	Q87
Manufacture of other transport equipment	C30	Other personal service activities	S96

As noted earlier, coal mining (NACE code B05) and manufacturing of basic pharmaceutical products and pharmaceutical preparations (NACE code C21), although initially included on this list, were excluded, as they are either in sharp decline (coal mining) or heavily regulated with mostly enclosed processes (pharmaceutical industry) in EU countries. This, of course, does not mean that exposure in these industries does not occur (energy production from fossil fuels including coal remains strong in certain EU countries) or that the workers involved are less important than those of the industries included.

The industries listed in Table 2 should not be perceived as definitively including all industries where exposure to dangerous substance is an issue. The absence of some other industries where exposure to dangerous substances is documented and widespread is evident. For example, workers in the farming industry are well documented as being exposed to agrochemicals, antibiotics, microbial dusts and their secondary metabolites, and to process-generated substances such as silica and diesel exhaust particles. However, the prevalence of self-reported exposure within the EWCS for these specific industries was generally below 30%. Similarly, self-reported exposure to specific agents for some industries (e.g. to biological agents within the forestry and logging industry) are thought to be somewhat underestimated (Figure 4). These findings may not be surprising, considering that selection is based on responses to questions that were not tailored to our particular purposes, but the low prevalence might indicate a reduced awareness among workers regarding the dangers posed by specific exposures in their workplace. Other explanations for these findings and the frequency of self-reported exposures can also be offered. For example, both white- and blue-collar workers will be present in an industry, with the latter most frequently involved in several different specialised or intermittent jobs, which potentially reduces the positive responses from individuals. Nevertheless, despite these limitations, the EWCS at present provides a unique source of information related to working conditions, including exposure parameters in EU workplaces.

Figure 3: Frequencies of self-reported exposures to different types and forms of dangerous substances by EWCS participants employed in the industries identified by the selection process

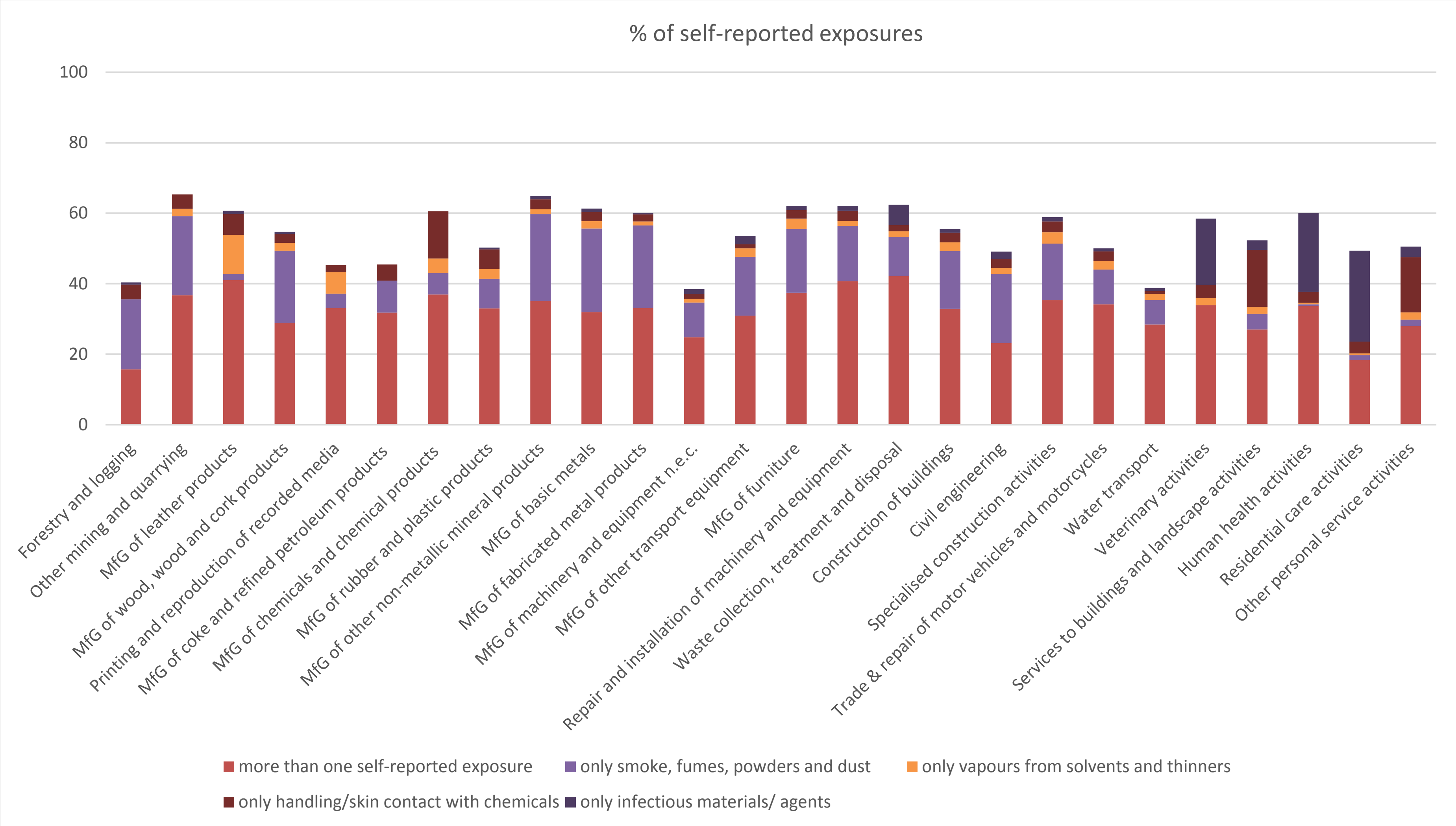
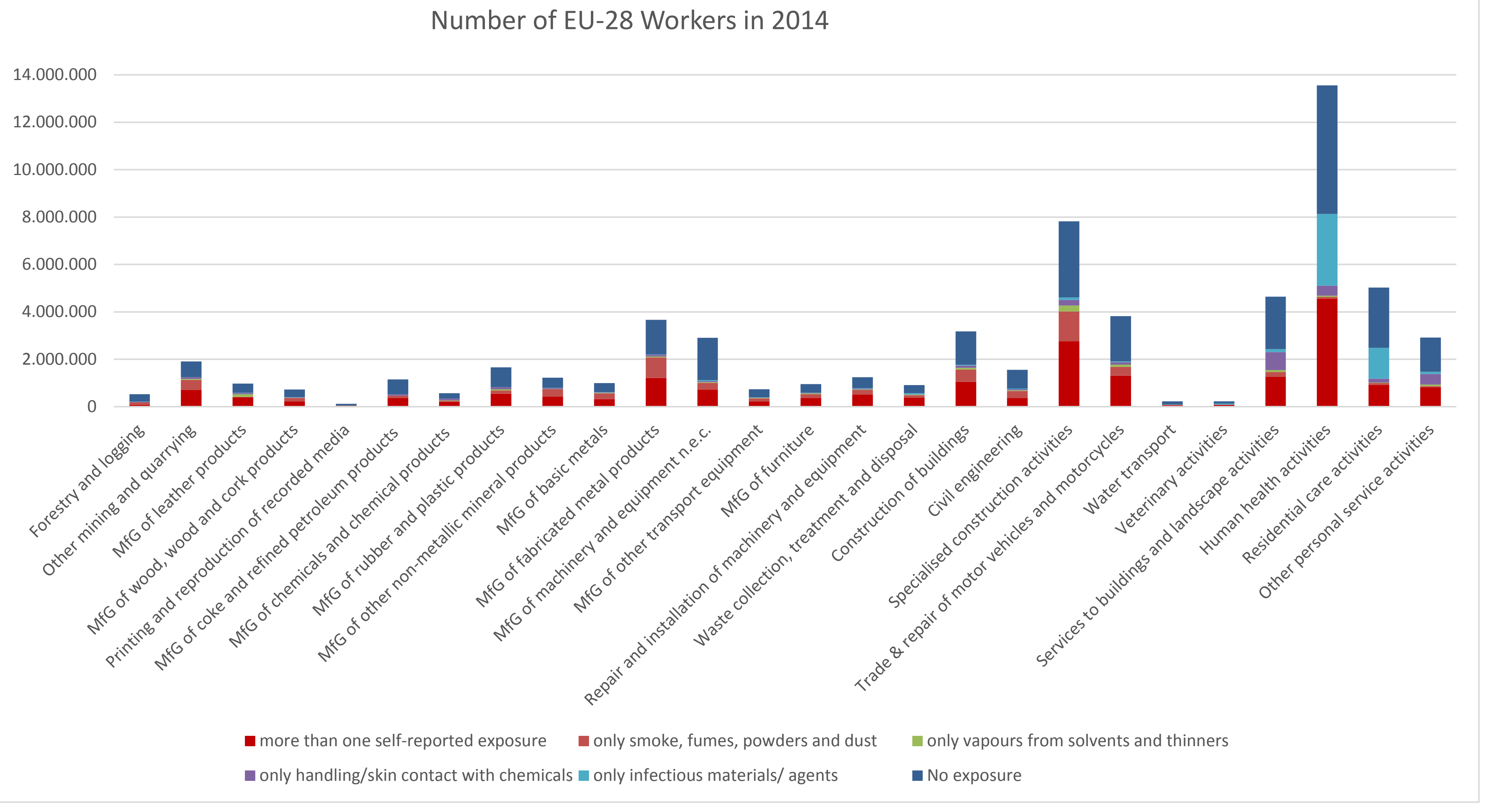


Figure 4: Estimated prevalence of exposure to different dangerous substances based on the EWCS results as a proportion of the workforce in the related industries of the EU-28



A more detailed analysis involving further stratification by job title, rather than simply by industry, would be desirable; however, this is difficult in practice given that the resolution provided in the EWCS on job-title code is at sub-major group level and, in many cases, overlaps with the NACE industry code. In addition, neither the EWCS nor the questions selected from it were tailored to our needs and this may, by itself, have led to a lower estimated exposure prevalence, due to the inability of some workers to recall precisely the time spent in exposure conditions, for example. The low estimated prevalence may also indicate a low awareness among workers regarding the dangers posed by specific exposures in their workplaces.

4.3 Exposure to dangerous substances within existing industries

An overview of the distribution of the 2,844 combinations of dangerous substances and industries identified by the analysis of the combined C&L Inventory and SPIN database and other sources is provided in Table 3. Similarly, the distribution of the 319 combinations remaining, following application of the selection criteria described above, is shown in Figure 4.

Table 3. Distribution of important dangerous substances identified across the 26 industries concerned

Industry	NACE v2.2 code	Number of substances*	% of total
Manufacture of coke and refined petroleum products	C19	99	3.5
Manufacture of chemicals and chemical products	C20	99	3.5
Manufacture of rubber and plastic products	C22	126	4.4
Manufacture of fabricated metal products	C25	89	3.1
Manufacture of machinery and equipment n.e.c.	C28	65	2.3
Manufacture of other transport equipment	C30	77	2.7
Specialised construction activities	F43	62	2.2
Wholesale and retail trade and repair of motor vehicles and motorcycles	G45	929	32.7
Water transport	H50	171	6.0
Services to buildings and landscape activities	N81	469	16.5
Other personal service activities	S96	222	7.8
Industries (n=15) with <60 substances each	Several**	436	15.3
Total		**2,844**	**100**

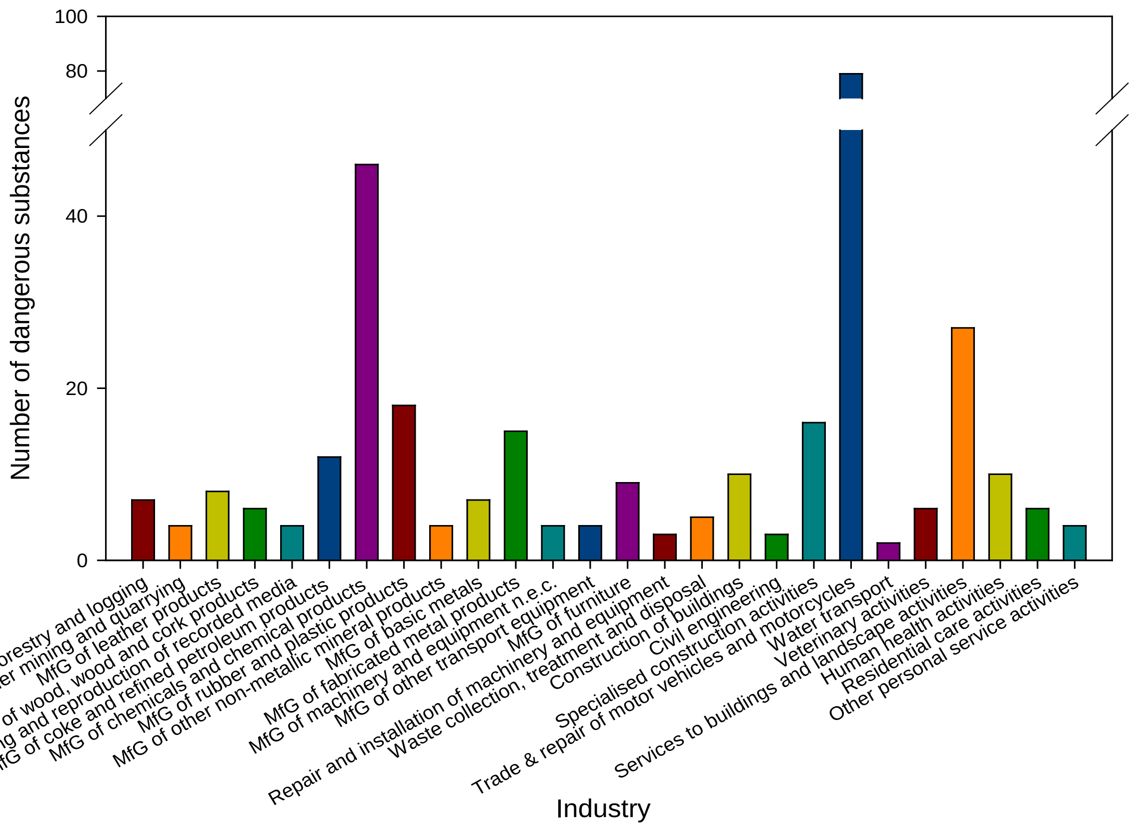
*Identified by the combined analysis of the ECHA/CLP Inventory and SPIN database and other sources (i.e. experts and literature); **includes (NACE codes) A02, B08, C15, C16, C18, C23, C24, C31, C33, E38, F41, F42, M75, Q86 and Q87.

The findings summarised demonstrate the ability of the data-driven methodology developed to identify important dangerous substances and to provide the quantitative data required for the analysis of trends in exposure and use. However, it is not free from drawbacks and limitations, including the inevitable biases of data-driven approaches, whereby analysis and selection favour those substances for which information on various attributes (e.g. hazard properties, quantities, usage) is available.

Other limitations relate to the characteristics of the databases used, such as the lack of standardisation in the industry and substance-coding systems used in different data sources. For example, whereas both SPIN and PRODCOM use NACE to code industries, the ECHA/CLP Inventory uses its own, SU, (Sector of use) industry classification system. This leads to a definition mismatch between sources for common industries, with some NACE-defined industry sectors being absent from SU classification (e.g. ‘Waste collection, treatment and disposal activities’ (E38), ‘The trade and repair of motor vehicles and motorcycles’ (G45), ‘Water transport’ (H50), ‘Veterinary activities’ (M75), ‘Services to buildings and landscape activities’ (N81) and ‘Other personal service activities’ (S96)).

Furthermore, such inconsistencies between databases extend beyond industry definitions to the dangerous substances themselves. More than 66% of all 2,844 dangerous substances identified following analysis of the SPIN database are used in industries not covered directly by the SU classification system. This suggests that some dangerous substances that are used within certain industries are not classified as such within the ECHA substance list, leading to an underestimation of the actual exposure condition involved. To further examine this, we looked at the number of dangerous substances reported as being used in ‘Manufacturing of coke and petroleum products’ (NACE code C19) within the SPIN database when mapped against the complete list of dangerous substances included in the CLP Inventory/ECHA substance list. Interestingly, the number of dangerous substances that the two databases have in common in this case was more than twice that of the number included in the current analysis, which utilised only substances registered as used in the ‘manufacture of bulk, large scale chemicals (including petroleum products)’ industry (ECHA code SU8).

Figure 5: Distribution of the 319 dangerous substances included in the final selection list



This suggests that, for similar exercises in future, it may be better to extract and use the complete list of registered dangerous substances within the ECHA list of substances (i.e. without applying stratification by industry under SU) in a combined analysis with the SPIN database.

Similarly to the limitations relating to industry sectors, not all dangerous substances are covered by the available databases utilised here. This is particularly relevant for those substances that are either process generated or have a biological origin (e.g. diesel fumes, wood dust, crystalline silica, viruses, bio-aerosols). Such substances are not covered by REACH and, usually being by-products of a process, they are not included in the CLP Inventory and there are no quantitative data on them registered in substance databases, see the OSH wiki article “process generated contaminants”: available at: https://oshwiki.eu/wiki/Process-generated_contaminants.

The limitations encountered in this work highlight the importance of including experts in our efforts to identify and analyse exposures to dangerous substances important for workers’ health. This allowed us to account for substances omitted by the selection process, or not considered in the selected databases, and to analyse their importance. However, the use of experts also has its own limitations (e.g. local versus wider international experience and contexts, and the depth and breadth of knowledge, experience and background more generally), so much so that steps must be taken to prevent related biases in the identification of industry-related substances. These naturally include, as far as possible, the standardisation of the expert evaluation processes, arbitration for disparity in results between experts and seeking a relatively broad geographical representation of expert knowledge to minimise gaps arising from differences between countries (i.e. where industries are present or prevalent in certain countries but not in others).

4.4 Are some dangerous substances more important than others?

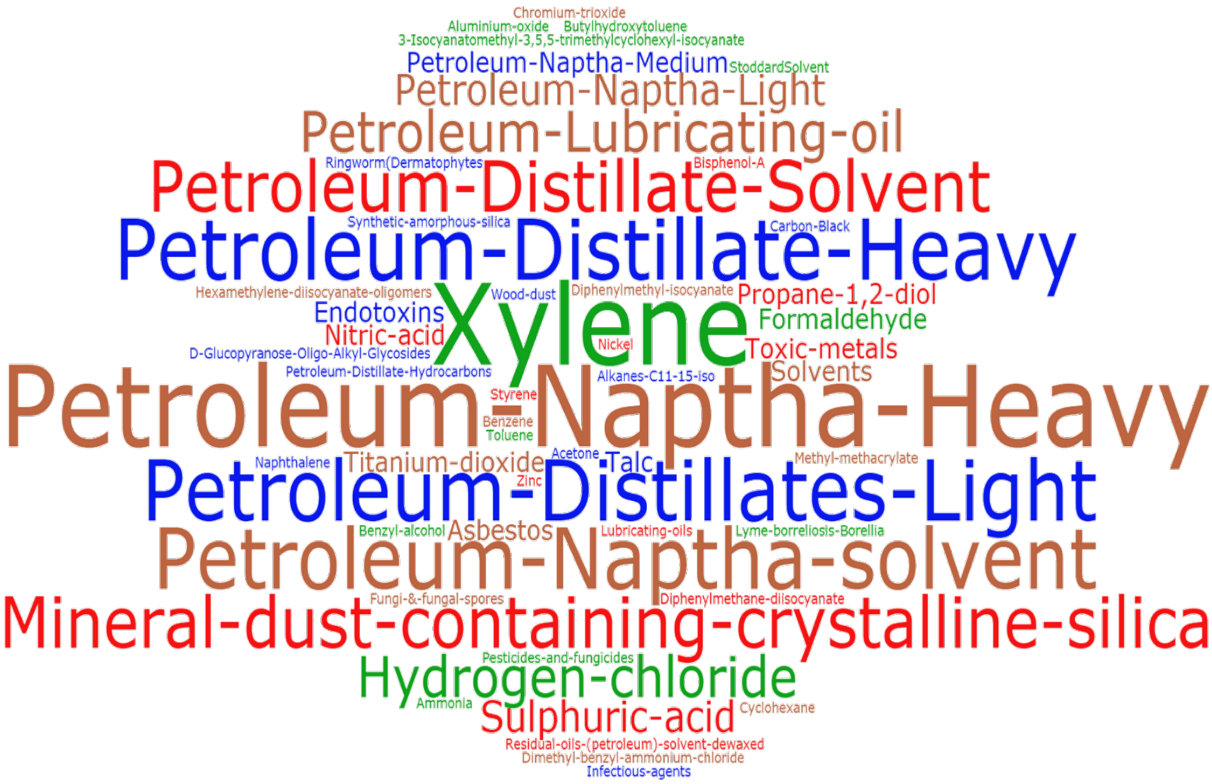
The levels of risk posed by dangerous substances vary, as do their importance. Dangerous substances have different hazard attributes and pose different risks to workers depending, among other things, on workplace and environmental conditions, the characteristics of the process involved and the probability of exposure. The area, size of the population affected and health and societal implications must also be considered, particularly when evaluations involve multiple substances and concern policy initiatives. In such cases, a systematic approach to identify and prioritise substances for the purpose of exposure prevention and control is needed. By devising the methodology described here and prototyping it for this project, we have been able to establish a list of dangerous substances and industries with priority status by combining publicly available data with expert evaluations using clear, well-defined criteria.

The process resulted in 115 combinations of dangerous substances and industries, which achieved an expert-assigned importance score of ≥6 for 68 unique substances. An overview of those substances weighted by the frequency of their appearance across industries is shown in Figure 6 and a full list is provided in Annex 2. Among these, there were 19 combinations with an importance score of ≥8. As subjects to be considered in the EU-OSHA campaign, it was agreed to highlight a shortlist of the top priority dangerous substances. The experts were asked to review the 19 combinations and select what they regarded as the five most important.

There was good agreement among experts in this final exercise and the substances selected include the following:

a. Silica: silica exposure occurs among construction, mining and manufacturing workers, and possibly also among workers in agriculture production and processing. Silica, as a process-generated substance, affects a broad range of industries and a large number of workers, with severe consequences resulting from exposure at both an individual and a societal/economic level. In addition, despite industry initiatives to increase awareness and minimise exposure, not all industries have joined these efforts (https://www.nepsi.eu/).

Figure 6: Word cloud summarising dangerous substances with an importance score of ≥6; the font size reflects the frequency of appearance within industries



b. Asbestos: exposure to asbestos (both intentional and accidental) occurs among construction and building workers. Although asbestos production or new use/installation of material containing asbestos is prohibited across all EU countries, current legislation allows any existing materials containing asbestos that are in good condition to remain intact. Such materials can commonly be found in commercial and domestic buildings built or refurbished prior to the year 2000. Therefore, exposure is particularly relevant for those workers within the construction industry who are performing repair or building refurbishments on such properties. Workers might or might not be informed about the presence of these materials, particularly in relation to domestic properties for which an asbestos assessment and management plan is not a legal requirement.

c. Solvents: solvent exposure can occur during printing both in the printing industry and more widely. Every commercial and domestic office, wholesale trade and retail corporation, institution and even home has installed and operating printers, which puts both workers and the public at risk of being exposed to solvents and emissions, including nanoparticles from the printing process. Despite the printing industry itself being in decline in terms of workforce size, the current ubiquitous nature of printers means the risks arising from their use has increased.

d. Non-infectious biological agents, particularly microbial cell-wall (e.g. endotoxins and beta-glucans) and fungal agents: exposure to such agents occurs in the waste recycling industry and more widely. Although not immediately life threatening, exposure to these inflammatory agents may lead to health conditions, such as chronic obstructive pulmonary disease, allergies and asthma, and severe economic and social consequences for both the individuals affected and society overall. There are currently no established occupational exposure limits for these agents and exposure in the workplace is difficult to control because of the large variability in exposure and the varied microbial nature of the agents themselves (e.g. self-replication). In addition, the recycling industry is relatively new and expanding in terms of both employment and output trends [11]. This industry's growth further increases the challenges and risks regarding the health and safety of the workers involved.

e. Wood dust: wood dust is a process-generated substance classified as a carcinogen, affecting large numbers of workers handling or processing wood within the construction, forestry and manufacture of wood articles and furniture industries.

To further extend this prototyping exercise, it was agreed that two 'top priority' substances would be selected for further examination by sourcing and providing more detailed information. Among the five substances (a-e above), the experts agreed that those of highest concern were silica and non-infectious microbial agents. For these dangerous substances, additional data collection and analysis was performed, including obtaining further detail on the use of the substances, exposure scenarios, the levels of exposure to workers while performing work tasks and the related health effects of exposure. Such detailed information was not available within the established and utilised databases (see Table 1 above) and was obtained primarily from rapid literature reviews. The advanced data summary sheets derived from this information are available within the main project report:https://oshwiki.eu/wiki/Developing_a_datadriven_method_for_assessing_and_monitoring_exposure_to_dangerous_substances_in_EU_workplaces.

4.5 Overall validity of the findings

This summary report describes the foundations of a method for assessing and potentially monitoring exposure to dangerous substances within EU workplaces, including a prototyping exercise and discussion on potential refinements of the method. The method combined publicly available data sources with direct expert evaluation and inputs to identify and prioritise those dangerous substances of concern. Overall, the method successfully identified 142 substances of particular concern across one or more of 26 relevant industries. Despite the successful application of the method itself, the prototyping exercise highlighted several issues with and limitations to the methodology that need to be considered in interpreting the findings summarised above.

Firstly, the SPIN database, which was the primary source of data regarding volume of substance use, comprises solely Nordic data. As such, it may not be fully representative of dangerous substance use from a broader EU perspective, in terms of trends in both the substance types and the amounts used. In addition, the approach taken (selecting substances on the basis of strict criteria for the amount of substances used) may have exacerbated this potential lack of representativeness. However, it was not feasible within this project to accurately assess the representativeness of the study findings at an EU level. Presently, there is no data equivalent to SPIN readily available for analysis from other EU countries, and the PRODCOM data do not refer to substance uses but rather to production volume.

Dangerous substances may be manufactured or produced by, used within or generated as a by-product of a process. The SPIN and PRODCOM databases include data on the volume of both chemical use and chemical production within different industries. However, neither covers dangerous substances that are process-generated or have a biological origin, such as silica, non-infectious or infectious bio-aerosols, wood dust and welding or diesel exhaust fumes. These substances are not covered by REACH or included in the C&L Inventory. Therefore, they could only be identified and included in this methodology through the input of expert knowledge and assessment, or possibly through the incorporation of data abstracted from exposure measurement databases such as MEGA (https://www.dguv.de/ifa/gestis/expositionsdatenbank-mega/index-2.jsp) if this were to be linked and analysed as part of the substance selection and trend-monitoring process.

In addition to process-generated substances, other important substances currently or historically used within industrial processes may also not be covered by the SPIN substance list or the ECHA/C&LP Inventory, either as a result of legislation or because they are still not widely used

[11] https://www.gov.uk/government/collections/digest-of-waste-and-resource-statistics

or used in considerable (sufficient) amounts across the respective industries. Some examples of such substances include asbestos, which was commonly used in construction prior to its prohibition, and carbon black, which is still used in the rubber, plastic and printing industries. As demonstrated by the present research work, employing experts to screen established lists for missing substances can, to some extent, compensate for any such biases.

Other limitations of the methodology previously mentioned include bias towards identifying and selecting substances with known attributes and including data on use and manufacturing and depending on the experiences and knowledge of the experts involved. Similarly, priority ranking by expert scores is another subjective component of the selection process, which, along with the lack of standardisation in industry, substance and job-title classification systems (coding schemes) between the databases used, may also impact on the results and conclusions of the study. However, the effects of many of those limitations can be reduced by mapping database contents and classification system correspondences, and by following best management practices when seeking expert opinion including, for example, adjudicating on opinion prior to implementation.

For the specific analysis presented in the main report of the project, the project requirements and logistics naturally constrained the selection of substances and the analysis of time periods available for the quantitative assessment of trends in this prototyping exercise. If the data had been more inclusive in terms of substances and data periods, the results could well have been different.

4.6 Outlook for the methodology established

The findings summarised in this report suggest that the established methodology could a) be applied to similar exercises in the future, with certain limitations and caveats; and b) form a substantial initial platform for the further development and establishment of a more permanent, scientifically sound and robust data-driven surveillance system on patterns of manufacturing of, use of and exposure to dangerous substances within the European Union.

Such a system, once available, could:

i. allow the regular monitoring of trends in use, manufacturing and exposure in relation to known or suspected dangerous substances in EU industries; the results of such analysis could potentially be used to provide early warnings for exposures arising from the increased use of known or emerging substances within certain industries and to promote targeted health and safety campaigns to prevent or control exposures to these substances in the workplace;

ii. enable better planning and policy development concerning substitution or restrictions in use for emerging dangerous substances; this will be possible given an improved harmonisation and integration of economic figures, some of which are already available within the SPIN and PRODCOM databases (e.g. annual value (in EU) of sold production);

iii. help plan and perform future burden of disease analysis at both national and whole EU levels, by suppling regular or even constant updates to existing information systems and monitoring tools such as CAREX[12] and SHECAN[13].

Some steps towards optimising the methodology established, and achieving the above, are summarised in Figure 7 and outlined briefly below:

[12] https://osha.europa.eu/en/tools-and-publications/publications/reports/report-soar-work-related-cancer

[13] Cherrie, J.W., Gorman, Ng. M., et al., *Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure to carcinogens and mutagens at work.* Edinburgh: Institute for Occupational Medicine, 2011.

a) Identify and integrate more databases that hold national and international data regarding substance use, production volumes and exposure measurements. Examples of such databases, comparable to the Nordic SPIN scheme, may include the substance register held by the Department of Labour Inspection of the Republic of Cyprus[14]; more recent relevant initiatives, such as the Belgian PROBE project[15]; and exposure databases, such as the UK's National Exposure Database (NEDB)[16] and the German Measurement Data Relating to Workplace Exposure to Hazardous Substances (MEGA) Database[17].

b) Map database/major statistical dataset contents, including similarities and differences (gaps and overlaps) between currently accessible product and substance databases.

c) Map in detail and standardise data registered under different industry (e.g. NACE and SU) and product/substance (e.g. PRODCOM codes vs CAS numbers) coding systems.

d) Map correspondence and remove peculiarities, including potential double entries, between coding systems (e.g. European Community-assigned substance numbers (EC numbers) and CAS numbers) used in the databases. Present analysis suggests imprecision in the labelling and identification of the underlying substance definitions/names.

e) Develop an integrated system and user-friendly interfaces to retrieve, collate, update and analyse the data. Once available, such a system will result in easy and standardised analysis and outputs for a range of interested stakeholders.

f) Extract and collate in the SPIN, EU employment and PRODCOM databases an unrestricted version of the registered substances within the C&L Inventory. Extractions of substance information from the inventory for the present prototype method adaptation have been performed at an industry level using the internal CLP industry classification as the restriction criteria. As discussed previously, such an approach may not cover all substances used within an industry and can provide information relevant to monitoring trends only for dangerous substances that are well recognised.

Finally, it is advisable that future adaptations of the present methodology be more inclusive and follow a more flexible approach when defining criteria of selection and representativeness for substance use across countries. This is essential to increase representativeness of selected substances across EU settings and to facilitate the establishment of an expanded pool of expert ratings. This pool if updated at well-defined time intervals will help the establishment of the previously described surveillance system, particularly in relation to its screening process.

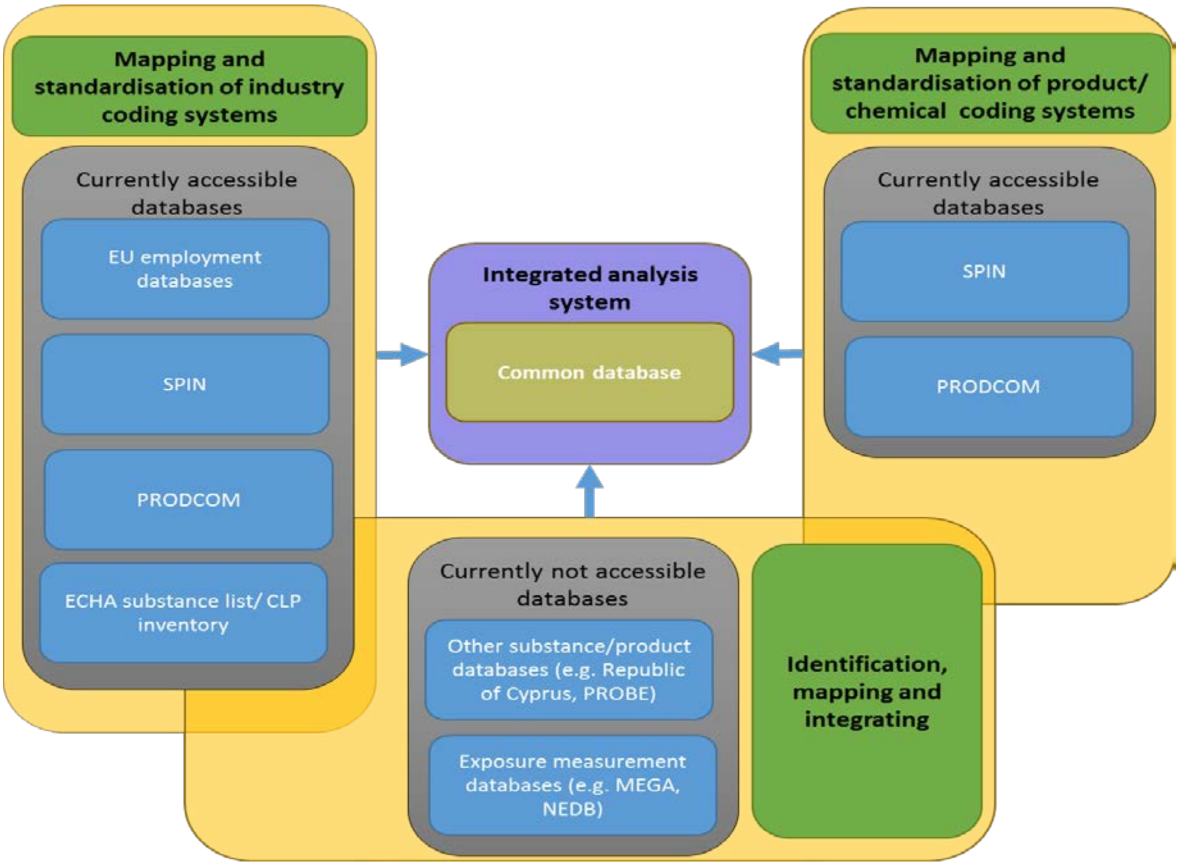
[14] http://www.mlsi.gov.cy/mlsi/dli/dliup.nsf/All/5D40BF12EBC2295BC2257E1100479BA9?OpenDocument

[15] Godderis, L., Pauwels, S., et al., 0264 Probe: hazardous chemical products register for occupational use in Belgium, *Occupational and Environmental Medicine,* 2017, 74:A81-A82.

[16] Burns, D.K., Beaumont, P.L.,The HSE national exposure database — (NEDB), *The Annals of Occupational Hygiene,* 1989, 33(1):1-4.

[17] https://www.dguv.de/ifa/gestis/expositionsdatenbank-mega/index-2.jsp

Figure 7: Schematic representation of the steps required to establish a platform towards a more permanent surveillance system



5 Conclusions

The present synopsis summarises a methodology established to provide a basis for building a surveillance system for monitoring quantitative developments concerning the manufacturing of, the use of and exposure to dangerous substances in the future. With a successful initial implementation, several dangerous substances, including those used in relevant industries, currently of concern to the health of workers in EU workplaces have been identified. In view of the study's findings, potential limitations and suggested next steps and improvements to the elaborated methodology have also been identified and summarised.

6 Annex 1. Example of a ‘Dangerous Substance Data Summary Sheet’

Dangerous Substance Data Summary Sheet

Substance name:	Toluene
CAS No. (if applicable):	108-88-3
AKA / Synonyms / Sub-Groups:	Methacide; Methane, phenyl-; Methylbenzene Methylbenzol; Phenylmethane; Tolu-Sol; Toluol; Anisen For a full list please look here
Substance identified from:	CLP Inventory
CLP Classification and labelling	Classification: H225, H315, H304, H336, H373, H361d GHS02, GHS07, GHS08
Industries (NACE R2 code) for which the substance is relevant:	Manufacture of coke & refined petroleum products (C19), Manufacture of chemicals (C20), Construction of buildings (F41), Specialised construction activities (F43)
Expert evaluation score(s)*	Manufacture of coke & refined petroleum products: 5 (1,2,2) Manufacture of chemicals industry: 6 (3,1,2) Construction of buildings: 5 (3,1,1) Specialised construction activities: 5 (3,1,1)
Employment characteristics	
Total number of employed persons in these industries within the EU 28 (2015)	Manufacture of coke & refined petroleum products: 111,827 Manufacture of chemicals industry: 1,100,000 Construction of buildings: 3,643,788 Specialised construction activities: 7,942,979
Trends in employment within industry (2008-2015)	Please, see figure 1

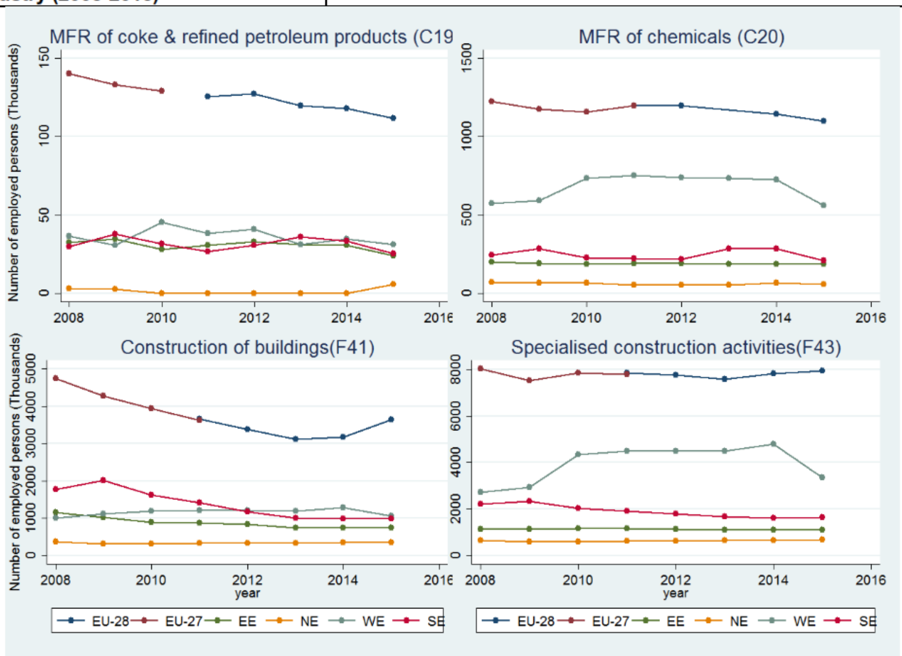


Figure 1 Trends in employment within industry (2006-2014) for geographical regions in Europe (EE=Eastern Europe, NE=Northern Europe, SE=Southern Europe, WE= Western Europe). Source of data: Structural business statistics (SBS) database.

Production/use characteristics	
Trends in amounts used or manufactured:	Please, see figure 2 and Table 1

Dangerous Substance Data Summary Sheet

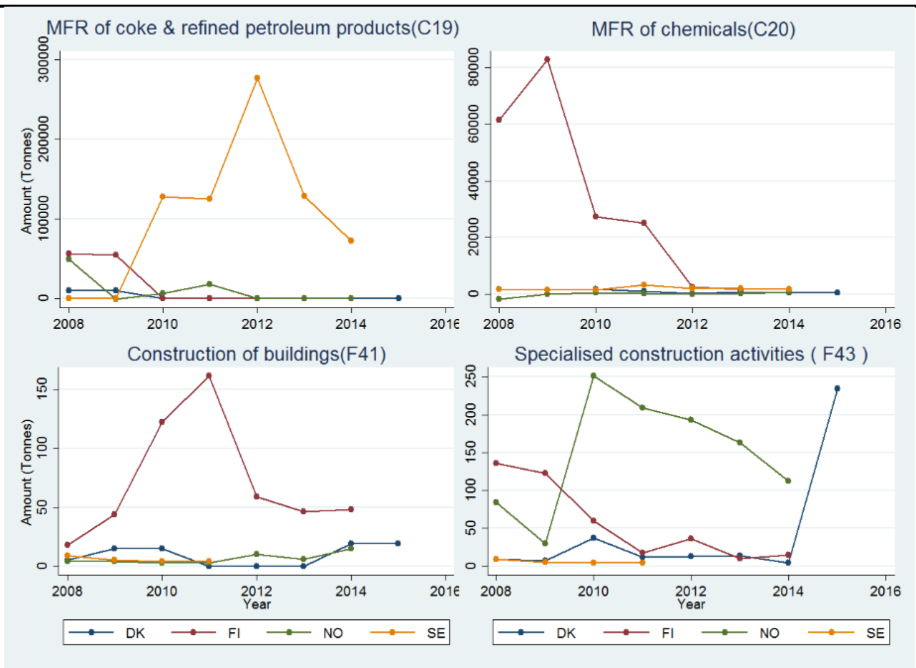


Figure 2 Trends in amounts of Toluene used within industries (2006-2014) in Nordic countries (DK=Denmark, FI=Finland, NO=Norway, SE=Sweden. Source of data: Substances in Preparations in Nordic Countries (SPIN) database

Table 1 Trends in total volume (in Tonnes) of Toluene produced (2008-2015) within the manufacturing of chemicals industry (C20) in EU, EAA and EU candidate member countries. Source of data: PRODuCtion Of Manufactured goods (PRODCOM) database code 20141225.

Country	2008	2009	2010	2011	2012	2013	2014	2015	Total
EU28	1,801,457	2,066,340	1,536,332	1,518,099	1,413,132	1,486,566	1,343,887	1,302,471	12,468,289
EU27	1,801,457	2,066,339	1,536,332	1,518,099	1,413,132	1,486,566	1,343,887	1,302,471	12,468,288
BE	C	57,760	66,743	C	57,822	72,222	57,763	25,269	337,582
CZ	21,533	12,432	19,624	22,351	18,712	C	C	C	94,652
DE	763,107	689,611	662,403	666,318	696997	706,041	636,322	591,337	5,412,136
ES	C	C	C	C	C	138,977	109,107	143,177	39,1261
FR	116,308	112,097	107,724	133,700	132,588	126,030	160,631	128,341	1,017,419
HR	0	1	0	0	0	0	0	0	1
HU	C	C	C	C	C	C	C	76,099	76,099
PL	NR	100,726	97,874	C	24,629	C	C	C	223,229
PT	140,608	119,728	98,809	116,987	114,255	154,253	121,282	125,323	991249
SK	C	C	C	C	C	C	C	41,934	41,934
UK	C	C	23	35	C	C	C	C	59

BE=Belgium, CZ=Czech Republic, DE=Germany, ES=Spain, FR=France, HR=Croatia, HU=Hungary, PL=Poland, PT=Portugal, SK=Slovakia, UK=United Kingdom. C= Confidential, NR=Not reported.
Note: The manufacturing chemical industries of Austria, Bosnia Herzegovina, Cyprus, Estonia, Ireland, Iceland, Lithuania, Luxembourg, Latvia, Malta, Montenegro, The Former Yugoslav Republic of Macedonia (FYROM), Norway, Sweden, and Slovenia do not appear to have produced any Toluene during the period 2008-2015. Bulgaria, Denmark, Finland, Greece, Italy, Netherlands, Romania, Serbia, Sweden, and Turkey appear to have produced Toluene within part of this period but the amounts have been confidential to the database.

Comments and observations	PRODCOM data suggest a downward trend in total production volume of Toluene following 2010. This is not surprising as Toluene is widely used in gravure printing and the volume of printed products is reduced amid the increased use of e-media.

* Score of the importance of the dangerous substance as evaluated by two independent experts based on a) the number of workers affected within a relevant industry, b) the likelihood of occurrence of the exposure to the substance and c) the severity of its health effects and impact on the daily life of the worker. Score scale 3-9 with 9 indicating the highest importance.

7 Annex 2. List and frequency of appearance of substances with an importance score of ≥6

Substance name	CAS number	Frequency of occurrence within industries
Pesticides and fungicides	NA	1
Wood dust	NA	1
Lyme borreliosis - *Borellia spp*.	NA	1
Distillates (petroleum), solvent-dewaxed heavy paraffinic	64742-65-0	5
2,6-di-tert-butyl-p-cresol	128-37-0	1
Formaldehyde	50-00-0	3
Solvents	Several	1
Benzene	71-43-2	1
Distillates (petroleum), hydrotreated light	64742-47-8	4
Distillates (petroleum), solvent-refined heavy paraffinic	64741-88-4	2
Naphtha (petroleum), hydrotreated heavy	64742-48-9	4
Naphthalene	91-20-3	1
Solvent naphtha (petroleum), heavy aromatic	64742-94-5	3
Solvent naphtha (petroleum), light aromatic	64742-95-6	6

Substance name	CAS number	Frequency of occurrence within industries
Metal zinc (powder)	7440-66-6	1
Titanium dioxide	13463-67-7	2
Cyclohexane	110-82-7	1
Distillates (petroleum), hydrotreated heavy naphthenic	64742-52-5	2
Naphtha (petroleum), hydro-desulfurized heavy	64742-82-1	3
Naphtha (petroleum), hydrotreated light	64742-49-0	2
Solvent naphtha (petroleum), medium aliphatic	64742-88-7	2
Toluene	108-88-3	1
Xylene	1330-20-7	8
Carbon black	1333-86-4	1
Styrene	100-42-5	1
Talc ($Mg_3H_2(SiO_3)_4$)	14807-96-6	2
Aluminium oxide	1344-28-1	1
Mineral dust containing crystalline silica*	*	4
Quartz (SiO2)	14808-60-7	1
Nickel	7440-02-0	1

Substance name	CAS number	Frequency of occurrence within industries
Cadmium, chromium, lead, arsenic, etc.— i.e. heavy metals	NA	2
Nitric acid	7697-37-2	2
Sulphuric acid	7664-93-9	3
Hydrogen chloride	7647-01-0	4
Chromium trioxide	1333-82-0	1
Microbial cell wall agents, mostly endotoxins	NA	2
Fungi and fungal spores (most importantly *Aspergillus fumigatus*, *Aspergillus flavus*)	NA	1
Ringworm / Dermatophytes	NA	1
Allergens incl. animal allergens — i.e. bovine, swine, cat and dog	NA	1
Asbestos	12001-29-5, 12172-73-5, 12001-28-4, 77536-68-6, 77536-66-4, 77536-67-5	2
Synthetic amorphous silica (registered as silicon dioxide in ECHA)	112926-00-8	1
Ammonia, aqueous solution	1336-21-6	1
Quaternary ammonium compounds, benzyl-C12-16-alkyldimethyl, chlorides	68424-85-1	1
Benzyl alcohol	100-51-6	1
D-Glucopyranose, oligomeric, C10-16 (even numbered) alkyl glycosides	110615-47-9	1

Substance name	CAS number	Frequency of occurrence within industries
Propane-1,2-diol	57-55-6	2
Lubricating oils (petroleum), C24-50, solvent-extd., dewaxed, hydrogenated	101316-72-7	1
3-Isocyanatomethyl-3,5,5-trimethylcyclohexyl isocyanate, oligomers	53880-05-0	1
Stoddard solvent	8052-41-3	1
4,4'-methylenediphenyl diisocyanate	101-68-8	1
Methyl methacrylate	80-62-6	1
Naphtha (petroleum), hydrodesulfurized light, dearomatized	92045-53-9	1
Acetone	67-64-1	1
Alkanes, C11-15-iso-	90622-58-5	1
Bisphenol (epoxy resin)	25036-25-3	1
Diphenylmethandiisocyanate, isomers and homologues	9016-87-9	1
Distillates (petroleum), hydrotreated heavy paraffinic	64742-54-7	1
Distillates (petroleum), hydrotreated light naphthenic	64742-53-6	1
Distillates (petroleum), hydrotreated light paraffinic	64742-55-8	1
Hexamethylene diisocyanate, oligomers	28182-81-2	1
Hydrocarbons, C3-4-rich, petroleum distillate	68512-91-4	1

Substance name	CAS number	Frequency of occurrence within industries
Lubricating oils	74869-22-0	1
Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based	72623-86-0	1
Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based	72623-87-1	1
Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based, high-viscosity	72623-85-9	1
Residual oils (petroleum), solvent-dewaxed	64742-62-7	1
Chemical agents, mainly benzene and solvents (i.e. turpentine, xylene, toluene, etc.)	Several	1
Infectious agents mainly Salmonella and Hepatitis, HIV and haemorrhagic viruses	NA	1

*Also referred to as respirable crystaline silica (RCS) or quartz (CAS number: 14808-60-7), which is the most common form.

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 1994 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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