WORKING FOR A HEALTHIER FUTURE

Project Number: P730
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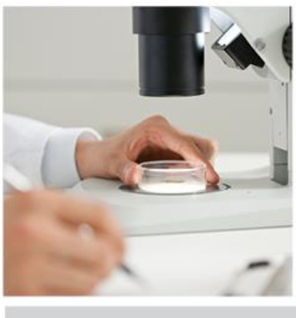
Development of a data-driven methodology to assess exposure to dangerous substances at workplaces in the EU by an advanced combination of existing data sources.

A project carried out in response to the EU-OSHA call: *Current knowledge on exposure to dangerous substances at work places in Europe.*

Project report

Ioannis Basinas, Richard Graveling, Ken Dixon and Peter Ritchie



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1 ABSTRACT

To support EU-OSHA's Healthy Workplaces Campaign 2018-19 on Dangerous Substances, the Institute of Occupational Medicine carried out a two-phase research study that developed a data-driven methodology to assess exposure to dangerous substances at workplaces in the EU. This involved the advanced combination of existing data sources. Firstly, information on substance exposure data sources and published measurements was compiled and analysed to establish a baseline of knowledge, and a strategy and methodology for their integration and assessment was developed and agreed. The approach was then implemented, enhanced, and tested to establish its feasibility. The methods:
a) extracted and combined data from existing databases (EU labour force, chemical properties, production and use), where overlapping coding schemes could be united;
b) used expert evaluation to examine, amend and rank the data, producing an agreed set of most dangerous substances;
c) populated comprehensive Level One (n=58) and more detailed Level Two Dangerous Substance Summary Sheets *(i.e. Crystalline silica (Quartz) in construction, mining, and manufacturing industries, and Non-infectious biological agents, particularly microbial cell wall and fungal agents, in the waste industry or more widely)*.
This report presents the methodology and results, including the Summary Sheets, and outlines the advantages and limitations of this new methodology.

2 EXECUTIVE SUMMARY

Introduction

This work was performed by the Institute of Occupational Medicine (IOM) on behalf of the European Agency for Safety and Health at Work (EU-OSHA) to provide insight into the development, in terms of trends in manufacturing, use and potential exposure levels to dangerous substances in European Union (EU) workplaces for the period 2000 to 2015. The main aim was to inform the development and content of the EU-OSHA Healthy Workplaces Campaign (HWC) 2018-19 on dangerous substances.

Specific objectives to be addressed, agreed through an iterative project management process by IOM and EU-OSHA, were to:

- Identify the hazardous substances and related industrial sectors that are of greatest concern regarding the exposure and health protection of workers.
- Develop a list of the most important industries and substances that can be scrutinised for and selected for inclusion in a more detailed evaluation concerning quantitative development in substance use and exposure.
- Examine, for a limited number of selected dangerous substances, the trends with respect to both levels of exposure and quantities in manufacture/use in order to guide priorities for the HWC 2018-19.
- Investigate the feasibility of, and provide stakeholders with the basis of, a scientific method that may be utilised in similar exercises in the future.

Working concept and strategy

Key representative EU data sources holding data from surveys on employment characteristics were combined with information sources on attributes, volumes of manufacturing and volumes of use of substances in Nordic countries and the EU, to develop a shortlist identifying the most relevant substances used within industries. Experts were asked to rate the shortlisted combinations of dangerous substances and industries by means of importance based on well-defined criteria. The assigned expert ratings were used to prioritise substances and select those of the highest importance for more in-depth assessment and campaign feedback.

The step-wise working strategy comprised five consecutive sub-tasks (ST), summarised as:

ST1. Industries where exposure to dangerous substances is potentially an issue were identified by analysing the European Working Conditions Survey (EWCS) data.

ST2. The most important of the identified industries in ST1 were then selected based on their workforce size and presence across EU countries using EU employment data.

ST3. The dangerous substances relevant to each of the selected industries in ST2 were then identified by using the hazard attributes registered in the ECHA Classification, Labelling and Packaging (CLP) inventory and by expert assessment.

ST4. For each dangerous substance identified in ST3 the availability of data within the Substances in Preparations in Nordic Countries (SPIN) database was scrutinized and the number of substances listed was reduced, based upon clearly defined selection criteria. The SPIN data for remaining substances was then analysed for time trends in use volumes for the period 2008 to 2015 and a short-list of candidate dangerous substance for further assessment was established. If available, PRODuCtion Of Manufactured goods (PRODCOM) data were also utilised.

ST5. The short list was examined and augmented with substances that were absent but known to be important, based on expert evaluation. Experts were also tasked with rating the substances based on well-defined criteria about a) their level of potential exposure and b) the size of workforce affected and c) their potential impact and health importance. A scale of 1-3, with three indicating the highest importance, was used for each of these parameters, and summed at the end to yield an overall score of importance (scale 3-9).

The expert ratings of ST5 were used to prioritise the substances and select, based on the overall score and expert opinion, those to be included in basic (level 1) and more advanced (level 2) substance summary information sheets. In order to avoid any confusion with somewhat similar existing substance information sheets (eg those from other ECHA or EU-OSHA sources) for the purposes of this research and report we refer to these as Dangerous Substance Data Summary Sheets. These cover aspects of the identification, labelling and classification of each substance alongside information on their industry relevance, health effects and related trends in employment, production and use volumes, and levels of workplace exposures. The Dangerous Substance Data

Summary Sheets together with the methodology comprise the major outputs of the project.

Data management and analysis

Depending upon the initial format available from the various source databases and requirements for analysis data was generally exported to MS Excel format to facilitate subsequent handling and, where required, collation or merging in an Access database. Data were summarised mainly in the form of total counts of observations, numbers of people employed and amounts of substances used overall and across specific years. Summaries of data extracted from the individual databases, including all graphical representations regarding time trends in amounts of dangerous substances were elaborated in STATA v13. Exceptionally relevant statistics from all of the EU employment databases were summarised and extracted from within their own web-based interfaces.

Results

Analysis of the EWCS data used a cut-off level of at least 30% self-reported prevalence of exposure to one or more agents of interest (e.g. smoke, fumes (such as welding or exhaust fumes), powders or dusts, vapours such as solvents and thinners and infectious materials) to identify 33 distinct industry divisions and classes of relevance. Based on the workforce size and representativeness across EU countries this list was further reduced to a final set of 26 industry divisions that had relevance for exposure to dangerous substances and were then considered in the further analyses.

Mapping of the correspondence between dangerous substances in the CLP inventory and the SPIN database for these 26 divisions resulted in the identification of 2820 relevant combinations of industries and substances with a further 24 combinations identified through expert knowledge. From those, 319 combinations fulfilled the established criteria concerning the presence and use of the dangerous substance in amounts exceeding 100 kg across all Nordic countries that provided data for the specific industry. There were 142 unique substances included in these 319 combinations relevant for one or more of the 26 industries. The importance of each combination was evaluated by the experts.

Overall, expert evaluations exceeded a score of 5 or above in 165 combinations and a score of 6 or above in 115 combinations that covered approximately 48% (n=68) of the 142 unique substances fulfilling the selection criteria. Level 1 Information Sheets were developed for each of these 68 substances.

For 15 unique substances used in 11 different industries (equivalent to 19 unique combinations) a score 8 or above was achieved. These were evaluated further for their importance. The Level 1 Data Summary Sheets for the 19 candidate combinations were fed back to the experts for final review and to select those that would be the subjects of the Level 2 Data Summary Sheets. Several proposals were put forward and through consultation with the experts and EU-OSHA this resulted in the identification of the following two priority substances at Level 2:

a) Exposure to crystalline silica within the construction, mining, and manufacturing industries, and
b) Exposure to non-infectious bio-aerosols such as fungal and cell-wall microbial agents among workers, particularly in the waste management and recycling industries.

Selection of the above included consideration of: crystalline silica's cross-industry occurrence and consequently the large numbers of potentially affected workers; the novelty and rapid growth of the recycling industry; the lack of adequate exposure control in many of the involved workplaces; and the consequences of exposures on both an individual's health and at the broader societal/economic level. More detailed Level 2 Data Summary Sheets were then developed for each of these substance /industry combinations.

Overall, the established approach seems capable of both monitoring these quantitative developments in relation to substance use and exposure, and of allowing the identification of dangerous substances relevant to the exposure and health of workers within specific industries.

Study limitations

Several limitations related to the study and the potential development of its methodology have been identified. Some of the most important include:

- As similar data are not available at a pan European level, the analysis of developments in quantitative volumes for most substances was based on the data included in the Nordic SPIN database. This may impact the extrapolation of the study results to a broader European perspective. However to enhance representativeness we aimed to describe substances identified as used across all Nordic countries wherever possible. Whilst it could not be not assessed in detail, the use of the SPIN data as a reference source for EU countries may be justified through an evaluation of the distribution of manufactured amounts and articles across EU countries in PRODCOM for products of commonly identified substances.
- Only UK based experts were involved in exercises to identify, evaluate and rate important dangerous substances across industries. This might have also impacted on study findings due to a potential lack of detailed knowledge on the industries and exposure conditions in other EU countries by the involved experts.
- Because of increased logistic requirements deriving from the lack of standardisation between information systems, analysis of the quantitative developments in substance use and/or production volumes and related employment statistics was restricted to the period between 2008-2015, which to some extent reduced our ability to meaningfully interpret time-related patterns patterns observed in the SPIN and PRODCOM data.
- Dangerous substances that are process-generated or those having a biological origin are not covered by SPIN and PRODCOM databases. In addition, the selection criteria applied required dangerous substances to have volumes of use >0 in all four Scandinavian countries. Though occasionally relaxed to accommodate the characteristics of certain industries, these restrictive criteria may have masked some relevant substances from our analysis. However it is reasonable to assume that any

impact of such a bias has been ameliorated by the involvement of the experts in the substance identification and selection process.

Suggested next steps

A careful evaluation of the present analysis results suggests that it is feasible for the methods established to form the basis for, or be directly applied to, similar exercises in the future. The established methodology could also form the initial platform for the development of a more permanent, scientifically sound and data-driven surveillance system concerning the patterns of manufacturing, use and exposure volumes of dangerous substances within the European Union. If in place such a system could have multi-dimensional benefits including establishing proactive and targeted exposure prevention and control initiatives as well as feeding future health impact assessments. Several important actions towards facilitating the above in the future have amongst others been identified, including:

- The detailed mapping and standardisation of the data registered under different NACE systems across the included databases (i.e. SBS, JSFQ, LFS, SPIN, PRODCOM and other relevant databases to be included) and of the correspondence between the PRODCOM codes and CAS numbers.
- The collection of the data and their analysis on the basis of different classification systems such as the European Community-assigned substance numbers (EC numbers).
- The extraction and collation to the SPIN, EU employment and PRODCOM databases of the complete list of registered substances within the ECHA inventory, with individual tables accounting for those details concerning CLP and industry classifications in the database.
- The integration of new databases holding national data regarding substance use and/or production volumes provided that a mapping exercise (summarised within the report) suggests that such data are likely available.
- The development of an integrated system and interfaces to retrieve, collate, update, and analyse the data in order to simplify the update, summary and interpretation of study findings.

Conclusions

The present study has been successful in providing an initial strategy and methodological basis for building a surveillance system for monitoring quantitative developments concerning manufacturing, use and exposure to dangerous substances in future. With the initial application of the established methodological framework, which combines the analysis of actual data with expert assessment using well-defined criteria to evaluate the importance of the dangerous substances, suggestions considering the upcoming 2018-19 “Healthy Workplaces Campaign” were also provided. In view of the study findings, potential limitations of and suggested improvements to the elaborated methodology have also been identified. These include, among others, the improved mapping and standardisation of the available data and coding systems applied, and the development of an integrated system and interfaces to retrieve, collate, update, and analyse the data in standardised and easy to read outputs.

3 INTRODUCTION

The Institute of Occupational Medicine (IOM) was contracted by the European Agency for Safety and Health at Work (EU-OSHA) to provide an analysis of European and national literature and statistical data that deal with the quantity and quality of current workplace exposure towards dangerous substances in the European Union. The work aimed to inform the development and content of the EU-OSHA Healthy Workplace Campaign 2018-19.

The specific research questions to be addressed under this programme of work, as specified in the Call for Tenders, were as follows:

- Achieving a better overview of the development of quantities of dangerous substances (exposure and use) at workplaces, be it manufactured, imported or process generated for the period between 2000 and 2015.
- Providing an overview of existing data on the exposures of specific groups (young and older workers, workers in service sectors and subcontracted workers) to dangerous substances.
- Providing information on the most important trends in exposure to certain groups of substances with serious health effects (e.g. carcinogens and mutagens, reprotoxicants, sensitisers etc.)

To answer these questions it was planned to adopt a staged, methodological approach, comprising of two main tasks as outlined in the call:

Task 1 - An initial phase to review trends in overall exposure and production volumes of dangerous substances in the EU and their prioritisation on the basis of well-defined criteria.

Task 2 – A further phase with a more in-depth and detailed assessment of the trends in use and exposure of those dangerous substances identified in Task 1 as highest priority.

3.1 GENERAL PROJECT MANAGEMENT LIAISON AND REPORTING

As proposed the project has been managed via the IOMs project management system. Project liaison and communication between IOM and EU-OSHA has been very good throughout, with regular updates and also email exchanges of additional information (eg Strategy documents, drafts of reports, Data Summary Sheets and other documents). At the initial kick-off teleconference meeting it was agreed that the IOM team and EU-OSA would arrange monthly teleconferences, to provide updates on progress and allow the exchange and discussion of results, ideas, suggestions, etc, on a regular basis. This was maintained over the course of the project and was extremely useful, helping to shape the strategy and focus of the project, with notes of each meeting circulated subsequently. A record of project-sponsor meetings is in Table 1. The minutes are available in Appendix 1 of this report.

Table 1. Record of project-sponsor meetings

TC & Date	General contents /comments	Present: EU-OSHA ;

		IOM
TC00 – 21/12/16	Initial Liaison and Introductions to Initiate Project Set-Up	LL; KG, PR
TC01 – 19/01/17	EU-OSHA Project Officers and IOM Team Project Kick Off Meeting, overall plan and timetable, initial information/data collection and analysis strategy development	LL, ES ; PR, IB, RG, KD, KG
TC02 – 02/02/17	Team update on progress & admin & presentation of initial T1 Strategy	LL, ES ; PR, IB, RG, KD, KG
TC03 – 16/03/17	Team update on progress & admin & presentation of updated T1 Strategy	LL, ES ; PR, IB, RG, KD, KG
TC04 – 20/04/17	Team update on progress reports on T1 Data/Spin Strategy; involvement of experts, screening feasibility exercise concept discussed agreed, preps for Interim report	LL; PR, IB, RG, KD, KG
TC05 – 30/05/17	Update on progress and Interim Report (draft sent today; final draft after delay through illness, sent 12/06/17)	LL; PR, IB, RG
TC06 – 28/06/17	Update on progress and data collection/analysis and further agreement on Task1 and Task 2 Data Summary Sheets, and use of experts etc, & email follow up on drafts.	LL; PR IB, KD
TC07 – 10/07/17	Update on progress and data collection/analysis and further updates to Data Summary Sheets discussed and agreed, & email follow up on drafts, (pre-holiday period)	LL; PR IB
TC08 – 04/09/17	Update on progress and data analysis & Data Summary Sheet preparations. Discussion of Final report preparations & consider Bilbao meet.	LL; PR, IB, RG, KD
TC09 – 11/09/17	Confirmed agreement of Task2 / Level 2 substances, and update on progress and reporting timescales.	LL; PR, IB
TC10 – 21/09/17	Update on writing and report delivery and review	LL; PR, IB
TC 11 11/10/17	October update on writing and editing of Final Report and prep. for Bilbao meeting---	LL; PR, IB
02/11/17 Final Project Meeting.	Final project results presentation to EU-OSHA Project Officers and Communications Unit representatives at EU-OSHA HQ, Bilbao.	LL, ES, PR, IB, and interested others from EU-OSHA.

The Interim Report summarised the project findings from an industry based approach, and in liaison with EU-OSHA, served to confirm the direction of the remaining work on Tasks 1 and 2.

The present Final Report provides an overall account of the design, detailed methodology applied and results of the study. It includes an overview of the work performed including the identified literature and sources of statistical data and the list of prioritised dangerous substances together with the Level 1 and 2 Dangerous Substance Data Summary Sheets which form the major outputs of the present work for use by EU-OSHA.

3.2 INFORMATION ON WORKING CONCEPTS AND RESEARCH STRATEGY DEVELOPMENT

As noted above, the overall aim of the project was to provide EU-OSHA with insight into the development, in terms of trends in manufacturing, use and potential exposure levels to dangerous substances in EU workplaces in the period 2000 to 2015. In relation to the EU-OSHA Campaign, dangerous substances are defined as being chemicals, substances generated at work and/or biological agents.[1]

To address the study questions, IOM designed a methodology that provided a detailed inventory of data sources; to allow the investigation of trends in the quantity and exposure to dangerous substances across the EU. This proposed initial methodology included two consecutive phases - the first providing the inventory to be used for data source identification, extraction and merging and the second comprising the actual analysis of trends based on original data.

At the project kick-off meeting it was mutually recognised by IOM and EU-OSHA that the potential scale of an investigation of this nature could be vast, given that it could be both very wide ranging, and in great depth. Recognising the limited resources and timescale available, it was acknowledged that the project scope and outputs needed to be tightly restricted in order to deliver adequate results in time. It was also agreed by all stakeholders in the project that the strict timescales would severely impact the ability (somewhat later, following initial phases of investigation) to gain access to relevant, non-publically available, original data (e.g. restricted databases from other agencies) for use within the project. IOM needed to carefully integrate these considerations with the further development of its more detailed project plan and research methodology.

During the kick-off meeting EU-OSHA presented their requirements and desired outputs from the project. These were to provide an outline of the available knowledge concerning time-trends in exposure concentrations and quantities (e.g. production outputs) for the most relevant dangerous substances manufactured and used at workplaces in the EU, as well as process-generated substances, over the last 15 years, with a focus on groups of substances and industrial sectors. EU-OSHA advised that they were interested in a screening approach that will identify the most relevant hazardous substances in terms of production, output, use, and exposure concentrations. A short-list of selected substances will be output for this first task, with 2-3 substances from this list

[1] https://osha.europa.eu/en/healthy-workplaces-campaigns ; https://oshwiki.eu/wiki/Dangerous_substances_(chemical_and_biological)

being selected for the more detailed review with actual measurement data in Task 2.

Following the kick-off meeting, IOM developed a revised strategy for Task 1 with several different options for implementation for consideration by EU-OSHA. Following discussion it was agreed to establish a list of dangerous substances to be selected for review in a stepwise manner:

- The results of the 2015 European Working Conditions Survey (EWCS) were first explored to identify the industries/classes of activities that are most relevant in terms of exposure.
- Expert opinion (involving experienced hygienists and human exposure scientists) was then to be used to assign the 2-3 most relevant exposure/substances per classification group, including brief descriptions of their current use.

The final list of substances to be reviewed was to be derived after applying a set of criteria including assessing:

- Representativeness and use across EU countries, utilising information on production/use volumes available on manufactured products from the PRODuCtion Of Manufactured goods (PRODCOM) database for this. [2]
- The number of workers likely exposed.
- Health impact importance or potency of substance.

IOM also proceeded to augment the list of relevant databases/data sources, developing entry forms for the experts and extracting and analysing the relevant EWCS data. The exact methodology applied in the latter analysis was discussed in a teleconference TC3, 16/03/17, and the results available up to that time were presented. Minutes of the discussions during this meeting can be found in Appendix 1.

The complete results of the EWCS analysis were made available to EU-OSHA in late March 2017. EU-OSHA returned with input and comments which, in principle, suggested an alternative approach to identify and assign substances to industry divisions identified by EWCS. This would utilise the list of substances across sectors available from the European Chemical Agency (ECHA), and be combined with an analysis of the Substances in Preparations in the Nordic Countries (SPIN) databases. [3]

This revised approach was welcomed and tailored to project requirements by the IOM research team, who made suggestions for adaptation to EU-OSHA prior to a teleconference. At this meeting EU-OSHA expressed preference for this new approach over previous proposals. and henceforward IOM proceeded with and practical refinements and its implementation.
The agreed working strategy and exact underlying methodology applied, as well as their results, are detailed in the sections that follow.

[2] http://ec.europa.eu/eurostat/web/prodcom
[3] http://spin2000.net/

3.3 WORKING STRATEGY OVERVIEW

As noted previously the study was, as proposed, designed in a stepwise manner comprising two related, consecutive tasks. These were:

a) **Task 1** – Dangerous substance identification and investigation, with objectives to:
   1. Identify the hazardous substances and related industrial sectors that are of greatest concern regarding the exposure and health protection of workers.
   2. Provide a list of industries and substances that can be scrutinised for and selected for inclusion in Task 2.
   3. Investigate the feasibility of, and provide stakeholders with the basis of, a scientific method that may be utilised in similar exercises in the future.

b) **Task 2** – In-depth examination of a limited number of dangerous substances, with the objective to provide a detailed assessment of the trends in dangerous substances with respect to both levels of exposure and quantities in manufacture/use for a two or three dangerous substances selected as priorities from the results of Task 1.

3.4 FINAL AGREED STRATEGY AND KEY DATA SOURCES

At the conclusion of the iterative process outlined previously, a practical working strategy was agreed. This strategy comprised a well-structured, objective methodology using key representative EU data sources and quantitative data to identify the most relevant dangerous substances. Outputs in terms of priorities for the EU-OSHA campaign would be Dangerous Substances Data Summary Sheets, at level 1 from Task 1 and, in enhanced level 2 detail for two selected substances in Task 2. Furthermore, in addition to providing the essential information sought by EU-OSHA, whilst we would not have the resources to develop this into an automated process, the methodology would significantly outline the structure and function of such a process, and also help assess its feasibility in terms of the availability, suitability and quality of information sources, and the practicalities of extraction and collation. The key components of this approach are shown on Figure 1 and are summarised below in five consecutive sub-tasks (ST):

ST1. Industries where exposure to dangerous substances is potentially an issue were first identified by analysing the European Working Conditions Survey (EWCS) data.

ST2. The most important of the identified industries in ST1 were then selected on the basis of their workforce size and presence across EU countries according to EU employment data.

ST3. The dangerous substances relevant to each of the selected industries in ST2 were then identified by using the hazard attributes registered in the ECHA Classification, Labelling and Packaging (CLP) inventory and by expert assessment.

ST4. For each dangerous substance identified in ST3 the availability of data within the Substances in Preparations in Nordic Countries (SPIN) database was scrutinized and the list of substances was reduced, based upon clearly defined selection criteria. The SPIN data for remaining candidate substances was then analysed for time trends for the period 2008 to 2015 and a short-list of candidate dangerous substance for further assessment was established. This short list of candidate substances was used in an analogous data availability exercise performed using the PRODCOM database.

ST5. The short list was examined and augmented with substances that were absent but known to be important, based upon the opinion of independent experts who were tasked with rating the substances based on defined criteria about their level of potential exposure and the size of workforce affected and the potential impact and health importance.

The ratings made by the experts in ST5 were used to prioritise the substances, and then select those to be included in the Dangerous Substance Data Summary Sheet summaries of Task 1 and, with further input by the experts, to select the two substances to be examined in Task2.

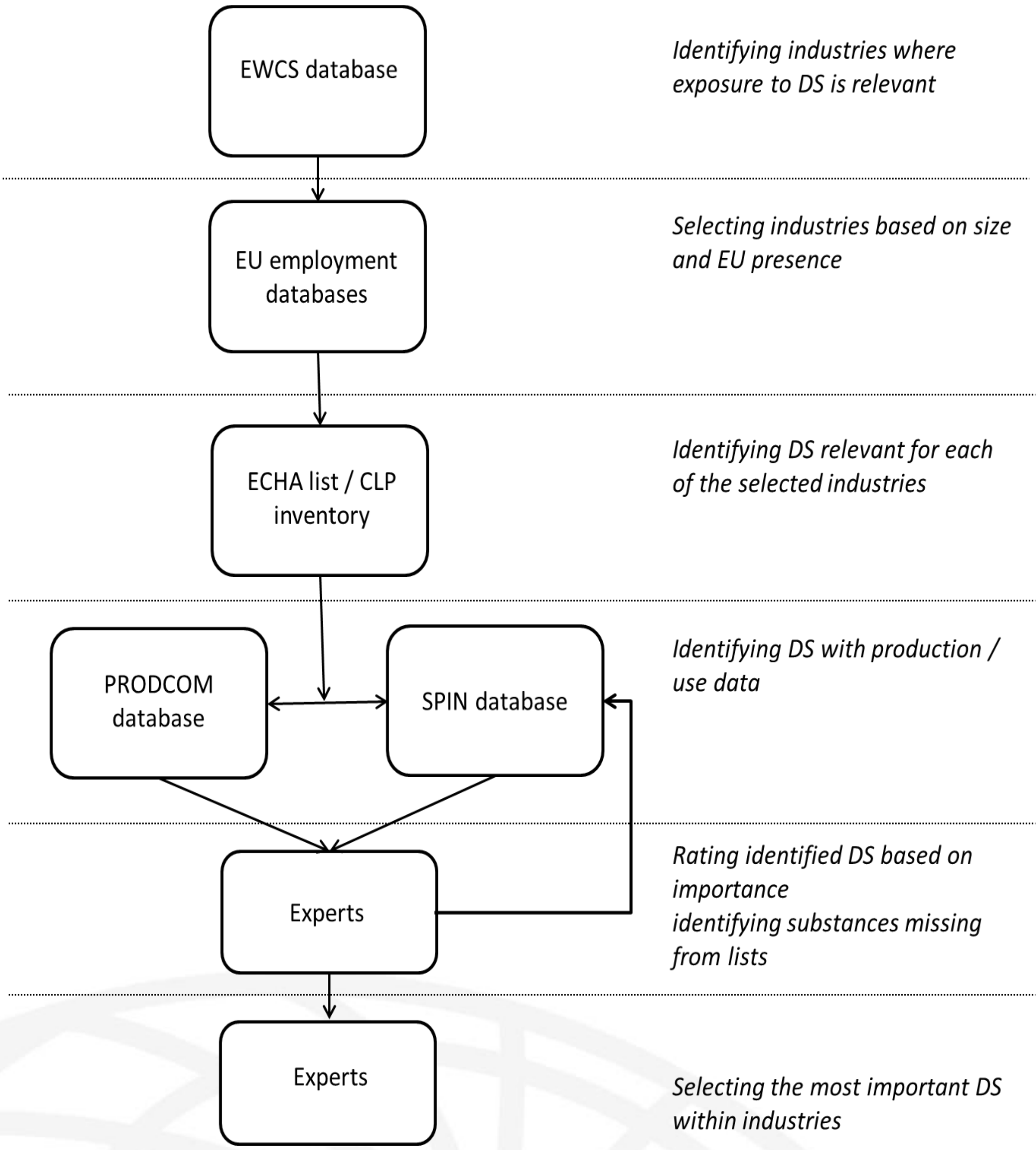

Figure 1. Schematic representation of the project working strategy for Task 1.
Notes: EWCS=European Working Conditions Survey; DS=Dangerous Substance; ECHA=European CHemicals Agency; CLP= Classification, Labelling and Packaging; PRODCOM=Production Of Manufactured goods; SPIN=Substances in Preparations in Nordic Countries.

The following sections provide further detail on the major components of the research and its execution. Firstly the databases used to identify and assess Dangerous Substances within the project are described (section 2.3), followed by methodological details including the criteria used to select and/or exclude substances from the list of candidate substances in each of the sub tasks described above (section 3.1). The background to the selection of substances in Task 2 is provided (section 3.2) alongside details of the data analysis performed and synthesis of its output (section 3.3). The results of the Task 1 (section 4.1) and Task 2 (section 4.2) are then briefly presented and a discussion of the findings and general prospectives of the undertaken work is provided in sections 5.

3.5 OVERVIEW OF PROJECT DATA SOURCES

3.5.1 The 2015 European Working Conditions Survey (EWCS) database

The EWCS was established and performed by Eurofound (European Foundation for the Improvement of Living and Working Conditions) with the aim of providing an overview of working conditions in Europe. It has been performed on a quinquennial basis since 1990[4] across European counties using a questionnaire covering, in its current form, details related to employment status, working time duration and organisation, learning and training, physical and psychosocial risk factors, health and safety, work-life balance, worker participation, earnings and financial security, as well as work and health. Furthermore, it includes items related to self-assessed exposure to a broad range of physical, chemical and biological agents. In general the questionnaire is designed to provide a comprehensive picture of the everyday reality of men and women at work. Between 1,000-3,000 workers per EU country are randomly selected from a statistical cross-section. In the latest round of the survey (2015), interview data from nearly 44,000 workers across 35 countries were collected. Copies of the questionnaires used, together with the final databases are publically available from Eurofound data services.[5]

3.5.2 EU employment databases

To support the development of its policies, EU member states run regular labour market surveys in a standardised manner. The results of these surveys (which are largely industry based) are compiled, stored, analysed and made available by EUROSTAT. For the present study we searched the databases of EUROSTAT to identify those surveys that were most representative of the industries identified as relevant for workers exposure to dangerous substances. The main sources of data that we used were as follows:

- *The Structural business statistics (SBS) EU database*,[6] which provides business data including labour statistics for the industry, construction, trade and services sectors. Agriculture, forestry and fishing, public administration and (largely) non-market services such as education and health are not covered by the database. The majority of the data is collected by the National Statistical Institutes (NSIs) by means of statistical surveys, business registers or from various administrative sources. Regulatory or controlling national offices for financial institutions or central banks often provide the information required for the financial sector. Quality assurance of SBSs is ensured through various statistical methods depending on the data source, such as grossing up, model based

[4] http://www.eurofound.europa.eu/surveys/european-working-conditions-surveys/fifth-european-working-conditions-survey-2010
[5] https://www.eurofound.europa.eu/surveys/about-eurofound-surveys/data-availability#datasets
[6] http://ec.europa.eu/eurostat/web/structural-business-statistics

estimation or different forms of imputation. Data is collected annually and provides information on:

i. Business demographics (e.g. Number of enterprises)
ii. Business outputs (e.g. Turnover, Value added)
iii. Business inputs, such as labour characteristics (e.g. Employment, Hours worked); goods and services characteristics (e.g. Total of purchases); and capital input (e.g. Material investments)

- *The Joint Forest Sector Questionnaire (JFSQ) database,*[7] which provides information on production and trade in roundwood and wood products (including primary and secondary products), the economy of forestry and logging, employment and sustainable forest management, comprising forest resources (assets) and environmental data. The data are compiled through annual questionnaires collected at a National level as part of a worldwide exercise in which Eurostat is responsible for the EU and European Free Trade Association (EFTA) countries.

- *The European Union Labour Force Survey (EU LFS),* which is conducted in the 28 Member States of the EU, 2 candidate countries and 3 countries of the EFTA in accordance with Council Regulation (EEC) No. 577/98 of 9 March 1998.[8] This is a large household sample survey providing quarterly results on labour participation of people aged ≥15 as well as on those who are outside the labour force. The surveys are conducted by the national statistical institutes across countries and compiled in common and harmonised databases by Eurostat. The contents include tables on population, employment, working time, permanency of the job, professional status etc. Stratifications by age, sex, education level, economic activity and occupation are provided where applicable.

3.5.3 The Substances in Preparations in Nordic Countries (SPIN) database

There is a long tradition in Nordic countries of establishing, entering and maintaining information relevant to the public on National registers. Within this framework Denmark, Finland, Norway and Sweden have established registers where details in relation to downstream uses of chemical substances in products on each country's National market are registered and maintained. SPIN is a common database that contains "non-confidential" information on substances from each of these Nordic product registers. The database was the result of a coordinated approach to harmonise the Nordic product registers and make related information widely available to the public. [9] No similar data are available in a pan European level which makes SPIN a unique and valuable resource of information concerning downstream use of substances both at an EU and national market level.

[7] http://ec.europa.eu/eurostat/web/forestry/overview
[8] http://ec.europa.eu/eurostat/web/microdata/european-union-labour-force-survey
[9] http://spin2000.net/

Substance data in the database is held by name, CAS-number, EC-number and registered information includes the number of products containing the substance, annual tonnage, industrial and use categories, and presence or absence of the substance in consumer products. Semi quantitative indicators regarding exposure are also provided for each substance. These are derived from index tools developed for the assessment of:

a) The potential "worst case" exposure to different target groups in the society and the environment (use index);
b) The broadness of use of a substance within a Nordic country (range of use index) and;

The use or not of a substance in the production of articles/goods (article index).

3.5.4 The ECHA list of registered substances and Classification, Labelling and Packaging (CLP) inventory database

The ECHA list of registered substances contains information on substances from the registration dossiers submitted to ECHA. This is a regulated process where registrants are obliged to provide information on the substances they manufacture or import. Within the ECHA list of dangerous substances, several substance-related data are available, including hazardous properties, classification and labelling according to the Classification, Labelling and Packaging (CLP) Regulation and their safe use. The web-based service list offers a search engine where users can filter results to return substances of interest: by hazardous properties according to CLP; by industry sector in which they are used; by type of process involved; and by production life cycle.[10] Classification of industries is based on an internal coding system that is partly linked (joined in a sub-code) to NACE Rev. 2,[11] the names of substances are provided as common and alternative(s), and coded by CAS- and EC- numbers.

3.5.5 The PRODuCtion Of Manufactured goods (PRODCOM) database

The PRODCOM database compiles National statistics on the production of manufactured goods within European countries. Data are collected at least annually through surveys conducted by questionnaire, targeted at enterprises likely to be producing particular products, established from the activity classification of enterprises in the business register. Registered data are linked to the NACE coding system of economic activities (NACE Rev. 2 from 2008 and onwards) and cover more than 3,900 products. Within the database, products are sorted by name and Statistical Classification of Products by Activity (CPA) in the European Economic Community codes. Statistics available include:

- The physical volume of production sold during the survey period
- The value of production sold during the survey period
- For some products, the volume of total production during the survey period

[10] https://echa.europa.eu/advanced-search-for-chemicals?p_p_id=dissadvancedsearch_WAR_disssearchportlet&p_p_lifecycle=0&p_p_col_id=column-2&p_p_col_pos=1&p_p_col_count=7

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

4 METHODS

4.1 DETAILED WORKING STRATEGY FOR TASK 1: REVIEW OF OVERALL TRENDS

4.1.1 Overview

To elaborate a list of dangerous substances relevant to the exposure and health of workers within the most important industries a multi-stage approach has been designed and applied. The particular stages comprising the process, as outlined earlier in Figure 1, are further described in the sections below.

4.1.2 Identifying industries where exposure to dangerous substances is relevant (ST1)

Relevant classes and groups of activities within the NACE classification were identified, based on the 2015 EWCS results (the latest available). During EWCS interviews subjects self-report their exposure to various groups of substances. Responses are given on a seven point scale from 1 to 7, ranging from “all the time” to “never”, with additional options for non-response and not-known. These are stratified across International Standart Classification of Occupations (ISCO)[12] edition 1988 and NACE revision 1.1 and 2 codes. Items of particular concern are E, F and G, H and I of Q29 of the interview which asked:

Please tell me, using the following scale, are you exposed at work to...?

E - Breathing in smoke, fumes (such as welding or exhaust fumes), powder or dust (such as wood dust or mineral dust) etc.
F - Breathing in vapours such as solvents and thinners
G - Handling or being in skin contact with chemical products or substances
H - Tobacco smoke from other people
I - Handling or being in direct contact with materials which can be infectious, such as waste, bodily fluids, laboratory materials, etc.

To analyse the data we reclassified the responses to the above questions as following:

a) Categories 1-5 (i.e. all the time; almost all of the time, around ¾ of the time, around half of the time, and/or around ¼ of the time): were all considered as indicating exposure was taking place
b) Categories 6-7 (i.e. almost never, never): were considered as indicating that no meaningful exposure was taking place
c) Categories 8-9 (i.e. don’t know, and no response) were treated as missing data

[12] http://www.ilo.org/public/english/bureau/stat/isco/

Following careful consideration of the available options regarding the relevant classification systems, it was decided to perform the analysis of hazardous substances at an industry level using the results coded by the NACE Classification Revision 2 (NACE v2) system, since revision 2 is the current version of the classification, established by Regulation (EC) No 1893/2006. As the most recent, it is more detailed (having 89 vs 64 branches) and representative in terms of existing production processes, compared to version 1.

It is important to highlight that exposure processes and patterns (i.e. substances, levels and variation) are most likely to be more representative and homogeneous under a classification system based on the occupation/job title within an industry. However it was not possible to achieve this with the data currently at hand, as the resolution in ISCO codes provided by EWCS is low (i.e. less detailed, as only codes up to the 2nd digit are provided – i.e. the sub-major group). At this resolution there was a large overlap between industries and occupations (e.g. both NACE and ISCO coding systems do not discriminate between different types of farms/farmers). However, even if resolution was higher, combining occupations with industries was likely to result in a very large number of small sized groups with reported findings being surrounded by large uncertainty.

The distribution of positive responses (i.e. indicating exposure) was examined across the relevant industry divisions (n=99) within the NACE v.2 classification system. Although not used further, a similar analysis was initially performed for the NACE v.1 and ISCO08 classification systems. Appropriate cut-off levels in terms of proportions of positive responses were then considered. A proportion of at least 30% of the participants reporting exposure to one or more of the agents of interest was selected; and applied as a cut-off level for identifying the most relevant industries to be included. Results were documented in an Excel database. This resulted in an initial list of 34 industry divisions where exposure to dangerous substances was highlighted as an issue.

4.1.3 Selecting industries based on size and EU presence (ST2)

The representativeness and importance of the industries included in the list up to this point was then assessed for their prevalence across EU countries and in terms of workers potentially exposed (defined as the number of persons employed within the industry). For this data were used from relevant EU databases providing business statistics across different economic activity sectors:

- For the industry, construction, trade and services sectors, data from the Structural Business Statistics EU database were employed;
- For health related trades the estimates for persons employed within the industries provided by the LFS results were used.
- For agriculture-related trades, relevant statistical figures were extracted from the JFSQ database.

Criteria for the inclusion of an industry were a) the presence in more than half of the 28 EU countries and; b) an overall involved workforce accounting into more than 100,000 persons across all EU countries.

4.1.4 Identifying dangerous substances relevant for each of the selected industries (ST3)

The approach selected to identify and assign substances to the industry divisions utilises the list of substances across sectors available from the ECHA source, combined with an analysis of the SPIN data. This was developed after discussion and suggestions provided by EU-OSHA, then tailored to project needs by the IOM research team. This was accomplished in the following two steps:

Step 1
The complete SPIN data from 2008-2015 (coded under NACE rev2) were downloaded as an MS Access database and the relevant subsets extracted for analysis for trends in use and representativeness across the four Scandinavian countries (see ST4). For data consistency and practical reasons (i.e. to enable the matching and merging of the various datasets in question within resources available) we used data for the period 2008-2015 where, again, the NACE rev2 classification system is in use. all relevant substances for an industry division were extracted which included data for both volumes and number of products used.

Step 2
Using the ECHA database system, substances used within certain industry divisions were identified using the relevant search engine. It should be noted that ECHA uses a slightly different industry classification system that in some areas does not fully overlap with the NACE codes. As the list of substances used per industry can be enormous, criteria to reduce the number of relevant substances were applied. These were based on the hazard-related property filters included in the search engine. This allowed substances to be screened in searches across industrial sectors based upon their selected properties with respect to carcinogenicity, mutagenicity, toxicity to reproduction, sensitization ability, and environmental toxicity. These attributes derive from the classification of substances in the CLP inventory and the relevant REACH dossiers. This classification enabled us to identify hazardous substances. To be inclusive an "OR" instead of an "AND" clause were used on the searches for hazard-related properties, so that substances were included in the search results if they were registered as having at least one of the above hazardous properties. For example, the division "Manufacture of leather and related products" had 1,166 substances registered as of use in the ECHA data. However, with the hazardous properties restrictions applied, just 76 substances satisfy the criteria for selection.

Some fine-tuning was required to cope with certain areas: Some industry divisions were not covered within the available ECHA classifications. For those divisions the approach was adapted to identify the dangerous substances of relevance. This depended on the processes and nature of agents likely to be involved. Details on such exceptions are provided in the relevant parts of the results section 3.1.4 below.

4.1.5 Identifying dangerous substances with data on production and use (ST4)

The results of the findings from the ECHA searches described above were exported in MS Excel file. This file was imported to the MS Access project database where they were merged with the SPIN data using CAS-number as the linkage variable. In the merge, based upon ECHA hazard properties, any substances not identified as hazardous were excluded from the SPIN dataset used – i.e. only those substances present in both sources (ECHA and SPIN) remained in the results.

Following exclusions, the remaining substances were analysed for trends and representativeness across the four Scandinavian countries. The number of substances selected was further restricted by the following criteria applied in sequence of appearance:

1. A substance needed to be present in at least three of the four countries to be analysed for trends and volumes.
2. A substance required to have volumes of use >0 (i.e. above 100 kg of use based on the SPIN definition) in all four countries in order to be preserved in the list.

Some flexibility and adaptations were required to fine tune the approach to fit the different make up of the source databases and initial efforts to match data. Following initial screening it was observed that, in some sectors, very few substances were identified in both ECHA and SPIN and they frequently were used in minimal quantities across no more than one or two countries. Application of the above criteria was therefore likely to result in complete dismissal of the industry from any further assessments. To acquire a reduced list of relevant substances for these industries (i.e. industries with fewer than 30 substances in the combined ECHA/SPIN database) the above criteria were relaxed, with lower requirements being applied for a substance to remain in the list. These included that a substance should be used in volumes >100 kg in at least one of the four countries. If this condition did not sufficiently reduce the list of acquired substances, then the presence of a substance across the four countries was also evaluated as point (b) above. Also, in cases where data on SPIN were not available for all four Nordic countries (e.g. NACE Code C33) the representation criteria were adjusted according to the number of countries that did provide data – e.g. in a case where only three of the four countries provided data on SPIN then a substance to be retained in the list required presence in two out of the three countries and volumes >0 in all three.

For the substances remaining in the list (following the selection and merging processes above) trends in their use for the period in question (2008-2015) were analysed.

Towards the end of ST4 and finalising the analysis, the resulting list of selected substances were tabulated by industry to form an assessment grid, similar to a

Job-Exposure Matrix [13] type table. This table was then provided to IOM and EU-OSHA experts involved in the project, who were asked to screen and expand the list of dangerous substances, based upon their expertise. Then for any newly identified substance added by the experts, relevant data within the SPIN database were mined and analysed for trends in use over the 2008-2015 period.

After input from all experts was completed (including feedback from ST5 described below), then the overlap between the final list of substances and the PRODCOM database was queried to retrieve appropriate PRODCOM data. The results of this exercise were exported and included as additional tables in the project database.

4.1.6 Rating identified dangerous substances based on their importance (ST5)

The latest Excel matrix of substances across industries was then provided to two IOM experts, who had not previously been involved in the project. They were asked to:

1) Screen the list of identified substances per industry and add hazardous substances not currently present that they thought were relevant for the industry and important for workers exposure and health.

2) For each industry, based upon their knowledge, rate the substances included in terms of their relevance using a three point scale, with 3 indicating the highest relevance, for each of the following three criteria:

   a) *Population: the number of workers currently potentially exposed to the substance within the industry*. Please consider the following numbers of potentially exposed workers as cut-off points:
      1. <100.000 persons then score = 1
      2. 100.000 – 250.000 persons then score = 2
      3. >250.000 persons then score = 3

   As assistance to this rating an overview of the numbers of persons employed within each of the industries in the years 2005 and 2015 was provided to the expert in another Worksheet ("persons employed").

   b) *Exposure: the likelihood of exposure occurring*. Please consider the following options based on classical simple hygiene principles:
      1. Substance used in processes that are unlikely to lead to exposure (e.g. fully enclosed conditions) – i.e. exposure is unlikely - then score = 1

[13] Goldberg M, Kromhout H, Guenel P, et al (1993) Job exposure matrices in industry. Int J Epidemiol 22 Suppl 2:S10-5.

2. Substance used in processes and conditions that cannot fully exclude exposure (e.g. both enclosed and non-enclosed conditions may apply, or RMM applied are not sufficient to completely exclude exposure as a result of the process. although exposure is not common) – i.e. exposure is possible - then score = 2
3. Exposure to the substance is common (e.g. substances used in manual spray-coating applications where exposure is relatively common) - i.e. exposure is likely – then score = 3

c) *Health and socioeconomic impact:* the impact of exposure on the health, working and social life of the worker. Please rate the relevance for substances using the definitions below as a rule of thumb:
   1. If the health effects of the substance is of an irritant nature (e.g. acute inflammation, mild irritation/sensitization reaction), with no or very small socioeconomic impact, then score = 1;
   2. if the health effects of the substance may impact on daily life, but they are not likely to be fatal (e.g. asthma) and socioeconomic impact is possibly large, then score = 2;
   3. If the health effects are severe (e.g. cancer, or death) and the socioeconomic impact is potentially large, then score = 3

Instructions were provided in writing alongside information on relevant employment data for each of the included industries that had been identified and extracted in ST2.

Once both expert evaluations were completed, so as to resolve any discrepancies between the experts and provide the project with arbitrated data, the results were collated and a third independent expert was asked to appraise the results and select the most satisfactory score provided by the first two experts.

4.1.7 Selecting the most important substances within industries (ST5)

The final outputs of the rating by the third expert were then used to calculate the overall score of relevance/importance for each substance in the table. This score, having a range between 3 and 9, was used to identify the most important industry and substance combinations, which are included in the synthesised summary results for Task 1. Dedicated Data Summary Sheets – Level 1 Data Summary Sheets - covering aspects related to the identification, labelling and classification of each substance alongside data on their industry relevance and related trends and characteristics in employment, use and production volumes has been included in these sheets. To keep to a reasonable number, within the resources available for production, these Level 1 summaries were limited to substances that had a score of 6 or more in one or more of the industries in which they were identified.

4.1.8 Updating the list of relevant information sources

Before the agreed strategy for data extraction was agreed, the project sought to identify suitable data and information sources that might be able to provide quantitative resources and data for use in analysis of trends for appropriately identified substances. Whilst the onus on data collection changed with the new agreed strategy, this information was compiled into a list of useful potential information sources. EU-OSHA provided IOM with a list of information on existing databases, used within their previous projects. This list was first updated by IOM with input directly from experts in this field. Relevant sources of information such as databases and publications were then identified through web and literature searches. These were shortlisted and screened in order to register their contents on a dedicated form, implemented in MS Excel.

4.2 DETAILED WORKING STRATEGY FOR TASK 2: DETAILED REVIEW OF TRENDS FOR SPECIFIC SUBSTANCES

Task 2 aimed to provide a more detailed analysis for a small number of substances selected from those identified in Task 1. This involved the collection and analysis of information additional to that collected and summarised in the Task 1 Level 1 Substance Data Summary Sheets. This particularly pertained to the uses of the substances, the scenarios and levels of exposure to the substance by workers while performing their task, and the related health effects exposure encountered. Presentation of the results was based on the further development of the Level 1 Substance Data Summary Sheets which were amended to accommodate the additional information above.

Selection of substances to be reviewed for Task 2 was primarily based on the scores assigned by the three experts in Task 1. Specifically, once these experts had provided their evaluations, a list was compiled comprising all substances that received an overall importance score ≥8. This list, together with Level 1 Dangerous Substance Data Summary Sheets for each relevant substance, was reviewed and evaluated by of a panel of five experts comprised of experienced scientists in the field of exposure and risk assessment and senior occupational hygienists. These experts then put forward suggestions for the most important substances to be selected and reviewed in depth in Task 2. Once agreement was reached, the five foremost combination of substances and industries suggested were put forward for discussion and agreement with EU-OSHA.

4.3 DATA PROCESSING AND MANAGEMENT

Data were summarised mainly in the form of total counts of observations, people employed and amounts of substances used overall and across specific years. Summaries of data extracted from the individual databases, including all graphical representations regarding time trends in amounts of dangerous substances were elaborated in STATA v13. Exceptionally relevant statistics from all EU employment databases were summarised and extracted within their own interface.

As indicated in the Methods section above, data was initially accessed online and, where appropriate, downloaded from a variety of different sources to allow the compilation of data used in the project to extract the dangerous substances for assessment, and ultimately the production of the Level 1 and 2 Data Summary Sheets. Depending upon the format available and the requirements for analysis the data was generally downloaded in, or exported from html tables to a MS Excel format to facilitate subsequent handling and, where required, its collation or merging. The latter was carried out by using an Access database, given its better facilities for selecting, re-shaping and merging (joining through SQL queries) related sets of data by the use of various key fields of interest, e.g. NACE Codes and CAS Codes.

The general data management methods for the various sources of data, as itemised in Table 2, are outlined below. Table 2 indicates the key data attributes of interest and when the data used in the project was downloaded (Acquisition Date). It should be noted that the contents of these data sources are updated periodically, thus their contents may have been updated since these extractions, which were effectively “snapshots” at the time. In most cases only new data would be added in the interim but, besides data updates, amendments to a repository’s facilities and functionalities, bug fixes etc, may alter the parameters of the data provided in future. Some changes are known to have been made in the ECHA online service since the ECHA data was extracted, but have not been explored.

Table 2. Key data attributes and acquisition dates for databases used in the project.

Dataset	Data source	Acquisition date	Nature of data	Key variables	Key coding schemes
EWCS	https://www.eurofound.europa.eu/surveys/european-working-conditions-surveys/sixth-european-working-conditions-survey-2015	02/2017	Exposure to physical and psychosocial risks, work organisation, work–life balance, and health and well-being	Industry code (NACE_R2) Job code (ISCO_08) Responses to sub-questions of survey item Q29 concerning exposures at work (Q29a; Q29b; Q29c; Q29d; Q29e; Q29f; Q29g; Q29h; Q29i)	Statistical classification of economic activities (NACE) revision 2 International Standard Classification of Occupations (ISCO) 08 edition
SBS	http://ec.europa.eu/eurostat/web/structural-business-statistics/data/database	03/2017	Employment statistics	Year (TIME) Country (GEO) Industry code (NACE_R2) Number of persons employed (INDIC_SB)	Statistical classification of economic activities (NACE) revision 2
LFS	http://ec.europa.eu/eurostat/web/lfs/data/database	03/2017	Employment statistics	Year (TIME) Country (GEO) Age(AGE) Gender (SEX) Industry code (NACE_R2) Number of persons employed	Statistical classification of economic activities (NACE) revision 2
JFSQ	http://ec.europa.eu/eurostat/web/forestry/data/database	03/2017	Production, trade and employment statistics	Year (TIME) Country (GEO) Gender (SEX) Education level (ISCED11) Number of persons employed (WSTATUS) Industry code (NACE_R2)	Statistical classification of economic activities (NACE) revision 2 International Standard Classification of Education (ISCED) 2011
ECHA / CLP inventory	https://echa.europa.eu/advanced-search-for-chemicals?p_p_id=dissadvancedsearch_WAR_disssearchportlet&p_p_lifecycle=0&p_p_col_id=column-2&p_p_col_pos=1&p_p_c	04/2017*	Substance register including info on classification, attribute, and use	Industry code (SU) Substance CAS number (casNumber) Hazardous properties (Properties)	Sectors of use (SU) Classification, Labelling and Packaging (CLP) for properties CAS Registry Number

	ol_count=7				
SPIN	http://spin2000.net/	04/2017	Substance and product register including use statistics	Year (year) Country (country) Industry code (NACE_code) Substance CAS number (SPINstof_CAS) Substance name (SPINstof_casname)	Statistical classification of economic activities (NACE) revision 2 CAS Registry Numbers
PRODCOM	http://ec.europa.eu/eurostat/web/prodcom	02/2017	Production and export data	Year Country Substance code (PRODCOM Code) Production and export volumes (Total volume) Label of PRODCOM code (LABEL)	Statistical classification of economic activities (NACE) revision 2 Statistical Classification of Products by Activity (CPA)

* Dangerous substance with no restriction by industry were extracted in 05/2017

- EWCS data: IOM was able to access the 2015 (6th) survey, via the UK Data Archive, and obtained a dataset with results of the questions of interest, and appropriate documentation. A Stata™ data file was downloaded and directly used for statistical summaries and tabulations. This provided substantial results that were presented in the Interim Report and also to feed into the process of selecting the substances for the Level 1 and 2 Data Summary Sheets. Given the analysis-ready nature of the dataset, and licencing restrictions on its use, this data was not further processed or added to the Access database.
- SBS, LFS and JFSQ data from Eurostat: for each of these sources the standard web interface was used to extract separate tables, for each NACE code, of employee numbers per year. After accounting for some formatting differences in column layouts between them, the data were concatenated into one large table, which was imported into the Access database to allow better selection, and merging with other data, and to enable the selective aggregation of figures by NACE, year, country, etc.
- ECHA data: The standard web interface was used to extract data, based upon their hazard levels for substances, into separate tables for each NACE code. These were imported into the database and combined values were concatenated into one large table for further combinations and aggregations
- SPIN data: Besides being available through a web interface this large database, made of a set of several interrelated tables, was also available as a downloadable MS Access database, making it straightforward to import and more efficiently manipulate data via Access SQL queries. Some rudimentary documentation is included to describe the basics of the database. After downloading, the data in the initial edition was automatically updated, and thereafter queried and linked as necessary to other datasets.
- PRODCOM data: This data was initially exported on large, complex tables from the Eurostat site, which were then concatenated and imported into the Access database. The large blocks of data had to be “reshaped” to rearrange the data so that it could be aggregated and summarised for the Data Summary Sheets. This was done by a series of SQL queries that resulted in the data being arranged by PRODCOM code by country and year.

The data management work was by necessity done in quite discrete steps as the work evolved: with the relatively exploratory, ad-hoc nature of the data extraction and manipulation needed for the various different types of data sets from different sources, it was not practical to develop a more sophisticated approach in the time available. In retrospect we can now see how this workflow can be improved upon to provide a more sophisticated, integrated system. This would automate much of the processing, and through a user-friendly, more automated interface, provide a simple query system, simplified reporting and export of results, and so on. In some cases data was maintained in Excel, and in others imported to Access for combination or merging, further manipulation and selection processes as required. Several combined datasets were exported for further analysis via STATA to better summarise results and produce graphs eg for number of workers per substance and industry, etc, for the Data Summary Sheets.

5 RESULTS

5.1 IDENTIFYING INDUSTRIES RELEVANT TO EXPOSURE TO DANGEROUS SUBSTANCES

The industries/classes of activities that are most relevant in terms of exposure to dangerous substances were identified through an analysis of the results of the 2015 EWCS. A detailed summary of the EWCS analysis results is provided in the Excel file attached as an online Appendix 2. Results are presented stratified by sub-question/substance involved and summary tables with all industry divisions with an >30% reported prevalence of exposure are also provided.

As discussed in the methods section above (Section 3.1.1), a proportion of at least 30% of the participants reporting exposure to one or more of the agents of interest has been used as a cut-off level to identify the most relevant industries to be included. The results of this analysis are summarised in Table 3 below comprising of 33 distinct industry divisions and classes. Cut-off levels at a prevalence of >20 and >25% were also considered, but the results in terms of numbers of divisions to be included in the assignments were excessive, as almost 50% of the available branches would have to be included under such a scenario.

Table 3. Industry divisions classified according to the (NACE) rev 2 coding system with more than 30% of the relevant participants at the 2015 European Working Conditions Survey (EWCS) reporting of being exposed to the agent in question for at least ¼ of their working time.

NACE v2.2 code (2-digit)	Description of NACE code	% of positive responses				
		Q29e - Exposed to smoke, fumes, powder and dust during work	Q29f - Exposed to vapours from solvents and thinners during work	Q29g - Handling or being skin contacted with chemicals during work	Q29h - Exposed to tobacco smoke from others	Q29i - Exposed to infectious agents during work
A02	Forestry and logging	33.8	7.6	15.2	16.6	4.8
B05	Mining of coal and lignite	72.3	40.4	40.4	31.9	25.5
B07	Mining of metal ores	100.0	0.0	0.0	0.0	0.0
B08	Other mining and quarrying	59.2	29.2	34.7	30.6	18.4
B09	Mining support service activities	22.2	27.8	38.9	11.1	11.1
C12	Manufacture of tobacco products	54.2	29.2	33.3	41.7	25.0
C15	Manufacture of leather and related products	18.1	46.2	41.0	6.9	20.0
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	47.1	25.9	20.5	14.5	9.9
C18	Printing and reproduction of recorded media	23.6	37.8	29.3	8.1	8.2
C19	Manufacture of coke and refined petroleum products	27.3	22.7	36.4	9.1	4.5
C20	Manufacture of chemicals and chemical products	29.4	29.7	47.2	7.2	14.4
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	12.0	17.6	33.9	3.6	19.3
C22	Manufacture of rubber and plastic products	33.0	30.7	30.7	7.9	12.6
C23	Manufacture of other non-metallic mineral products	51.7	26.2	28.6	14.2	14.2
C24	Manufacture of basic metals	53.6	28.9	23.8	13.9	12.4
C25	Manufacture of fabricated metal products, except	53.3	27.6	23.6	12.4	9.6

NACE v2.2 code (2-digit)	Description of NACE code	% of positive responses				
		Q29e - Exposed to smoke, fumes, powder and dust during work	Q29f - Exposed to vapours from solvents and thinners during work	Q29g - Handling or being skin contacted with chemicals during work	Q29h - Exposed to tobacco smoke from others	Q29i - Exposed to infectious agents during work
	machinery and equipment					
C28	Manufacture of machinery and equipment n.e.c.	31.6	19.4	18.1	9.2	8.9
C30	Manufacture of other transport equipment	42.9	29.8	22.6	6.0	9.5
C31	Manufacture of furniture	48.8	32.9	29.6	11.5	11.1
C33	Repair and installation of machinery and equipment	48.3	31.0	34.4	27.1	17.2
E38	Waste collection, treatment and disposal activities; materials recovery	46.2	24.0	25.0	24.3	39.3
E39	Remediation activities and other waste management services	40.0	31.3	37.5	18.8	43.8
F40	Construction	40.7	24.1	31.5	24.1	14.8
F41	Construction of buildings	44.8	25.3	27.4	31.4	14.8
F42	Civil engineering	41.3	18.1	18.5	19.6	11.0
F43	Specialised construction activities	45.4	29.1	30.0	24.5	14.4
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	40.1	28.5	30.5	18.1	10.9
H50	Water transport	31.0	22.4	22.4	21.7	9.5
M75	Veterinary activities	5.7	13.2	34.0	5.7	49.1
N81	Services to buildings and landscape activities	16.9	18.5	40.9	11.4	19.6
Q86	Human health activities	5.5	11.8	33.8	5.4	54.0
Q87	Residential care activities	3.7	6.1	19.1	10.9	43.1
S96	Other personal service activities	11.2	23.4	41.2	9.4	14.0

Following initial identification, the industries were screened further, based on their representativeness across EU countries and the number of workers potentially exposed, using information collected from relevant EU databases. As noted above if an industry was not present in more than half the 28 EU countries or if the overall workforce involved was rather small, amounting to only a few thousand persons across all EU countries, then it was removed from the list. Furthermore, industries in decline within the EU (i.e. coal mining) or those which were aggregations of smaller divisions that were already included were also removed from the list. These exclusions resulted in a list of 27 industry divisions to be considered in further analyses and in the assignment of dangerous substances. An overview of industries, together with the relevant findings considering the representativeness of these (in terms of EU coverage and numbers of workers exposed) is provided in Table 2. Following a review of the included industries, the division with NACE code C21 (manufacture of basic pharmaceutical products and pharmaceutical preparations) was also removed from the list, as it was regarded as a heavily regulated industry where production is performed mainly in enclosed conditions.

Table 4. Description and characteristics related to representativeness of divisions included in the final of industries to be assigned dangerous substances.

NACE v2.2 code (2-digit)	Description of NACE code	Source of employment and country data	No of countries with presence of industry	Total number of workers in EU in the period	
				2005	2014
A02	Forestry and logging	JFSQ	28	538,000*	525,700
A08	Other mining and quarrying	SBS	28	252,200†	1,911,870
C15	Manufacture of leather and related products	SBS	26	550,700	442,419
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	SBS	28	1,291,000	972,442
C18	Printing and reproduction of recorded media	SBS	28	1,000,000	727,735
C19	Manufacture of coke and refined petroleum products	SBS	28	159,900	117,892
C20	Manufacture of chemicals and chemical products	SBS	28	1,299,900	1,146,472
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	SBS	28	549,800	564,036
C22	Manufacture of rubber and plastic products	SBS	28	1,817,400	1,657,149
C23	Manufacture of other non-metallic mineral products	SBS	28	1,604,900	1,224,781
C24	Manufacture of basic metals	SBS	28	1,173,700	1,000,000

NACE v2.2 code (2-digit)	Description of NACE code	Source of employment and country data	No of countries with presence of industry	Total number of workers in EU in the period	
				2005	2014
C25	Manufacture of fabricated metal products, except machinery and equipment	SBS	28	3,842,800	3,663,178
C28	Manufacture of machinery and equipment n.e.c.	SBS	28	3,079,000	2,910,000
C30	Manufacture of other transport equipment	SBS	28	699,600	740,000
C31	Manufacture of furniture	SBS	28	1,284,000	955,521
C33	Repair and installation of machinery and equipment	SBS	28	1,378,000†	1,246,500
E38	Waste collection, treatment and disposal activities; materials recovery	SBS	28	738,100	914,320
F41	Construction of buildings	SBS	28	4,856,400	3,174,312
F42	Civil engineering	SBS	28	1,644,900	1,560,713
F43	Specialised construction activities	SBS	28	8,250,300	7,820,230
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	SBS	28	3,686,500	3,825,269
H50	Water transport	SBS	28	207,200	222,721
M75	Veterinary activities	SBS	28	184,700*	229,002
N81	Services to buildings and landscape activities	SBS	28	3,582,600*	4,640,341
Q86	Human health activities	LFS	28	12,750,200*	13,552,700
Q87	Residential care activities	LFS	28	3,893,700*	5,025,500
S96	Other personal service activities	LFS	28	3,148,700*	2,913,500

JFSQ= Joint Forest Sector Questionnaire; LFS= Labour force survey; SBS= Structural business statistics; *Summarised data are for the year 2008; †Summarised data are for the year 2006

5.2 IDENTIFYING DANGEROUS SUBSTANCES RELEVANT TO THE SELECTED INDUSTRIES

As part of the designed strategy data were extracted and analysed from the relevant ECHA and SPIN databases. Following a mapping exercise regarding the correspondence of the industry classification systems used between the two databases it was realised that no industry-specific data were available within ECHA for the following divisions:

- Waste collection, treatment and disposal activities; materials recovery (NACE Code: E38)
- Wholesale and retail trade and repair of motor vehicles and motorcycles (NACE code G45)

- Water transport (NACE code: H50)
- Veterinary activities: (NACE code M75)
- Services to buildings and landscape activities (NACE code: N81)
- Other personal service activities (NACE code: S96)

For these divisions alternative approaches to identify the most relevant dangerous substances were sought. This included data mining within SPIN, using the full (i.e. without industry specific filters) list of dangerous substances registered within ECHA; literature searching; and expert evaluations, as planned, for any of the identified industries. The actual sources of dangerous substances for each industry are summarised in Table 5. The results from the mapping exercise regarding the correspondence between the classification systems used within the ECHA and SPIN databases, as well as the numbers of substances identified through every approach involved and those included in the final list are also provided.

Table 5. Applied selection criteria and number of dangerous substances identified in the ECHA databases across the industry divisions of interest.

NACE v2.2 code (2-digit)	Description of NACE code	Information source	Relevant sectors according to ECHA classification	No of hazardous substances			
				Identified in ECHA	Common between ECHA and SPIN databases	Identified by experts and other sources	Included in final list (i.e. following exclusions)
A02	Forestry and logging	ECHA	SU 1: Agriculture, forestry and fishing	55	9	3	7
B08	Other mining and quarrying	ECHA	SU 2a: Mining (without offshore industries)	38	8	0	4
C15	Manufacture of leather and related products	ECHA	SU 5: Manufacture of textiles, leather, fur	78	24	0	8
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	ECHA	SU 6a: Manufacture of wood and wood products	51	23	0	6
C18	Printing and reproduction of recorded media	ECHA	SU 7: Printing and reproduction of recorded media	48	28	1	4
C19	Manufacture of coke and refined petroleum products	ECHA	SU 8: Manufacture of bulk, large scale chemicals (including petroleum products)	598	99	0	12
C20	Manufacture of chemicals and chemical products	ECHA	SU 8: Manufacture of bulk, large scale chemicals (including petroleum products) + SU 9: Manufacture of fine chemicals	801	99	0	46
C22	Manufacture of rubber and plastic products	ECHA	SU 11: Manufacture of rubber products + SU 12: Manufacture of plastics products, including compounding and conversion	298	125	1	18

NACE v2.2 code (2-digit)	Description of NACE code	Information source	Relevant sectors according to ECHA classification	No of hazardous substances			
				Identified in ECHA	Common between ECHA and SPIN databases	Identified by experts and other sources	Included in final list (i.e. following exclusions)
C23	Manufacture of other non-metallic mineral products	ECHA	SU 13: Manufacture of other non-metallic mineral products, e.g. plasters, cement	89	53	1	4
C24	Manufacture of basic metals	ECHA	SU 14: Manufacture of basic metals, including alloys	144	55	1	7
C25	Manufacture of fabricated metal products, except machinery and equipment	ECHA	SU 15: Manufacture of fabricated metal products, except machinery and equipment	94	89	0	15
C28	Manufacture of machinery and equipment n.e.c.	ECHA	SU 17: General manufacturing, e.g. machinery, equipment, vehicles, other transport equipment	118	65	0	4
C30	Manufacture of other transport equipment	ECHA	SU 17: General manufacturing, e.g. machinery, equipment, vehicles, other transport equipment	118	77	0	4
C31	Manufacture of furniture	ECHA	SU 18: Manufacture of furniture	51	14	0	9
C33	Repair and installation of machinery and equipment	ECHA	SU 17: General manufacturing, e.g. machinery, equipment, vehicles, other transport equipment	118	52	0	3
E38	Waste collection, treatment and disposal activities; materials recovery	Experts and literature	Not available	0	0	5	5
F41	Construction of	ECHA	SU 19: Building and construction	85	55	2	10

NACE v2.2 code (2-digit)	Description of NACE code	Information source	Relevant sectors according to ECHA classification	No of hazardous substances			
				Identified in ECHA	Common between ECHA and SPIN databases	Identified by experts and other sources	Included in final list (i.e. following exclusions)
	buildings		work				
F42	Civil engineering	ECHA	SU 19: Building and construction work	85	47	2	3
F43	Specialised construction activities	ECHA	SU 19: Building and construction work	85	60	2	16
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	ECHA	Not available. The full extract of substances classified as dangerous in ECHA is used.	15,150*	929	0	79
H50	Water transport	ECHA	Not available. The full extract of substances classified as dangerous in ECHA is used.	15,150*	171	0	2
M75	Veterinary activities	Experts and literature	Not available	0	0	6	6
N81	Services to buildings and landscape activities	ECHA	Not available. The full extract of substances classified as dangerous in ECHA is used.	15,150*	469	0	27
Q86	Human health activities	ECHA	SU 20: Health services	52	30	0	10
Q87	Residential care activities	ECHA	SU 20: Health services	52	17	0	6
S96	Other personal service activities	ECHA	Not available. The full extract of substances classified as dangerous in ECHA is used.	15,150*	222	0	4

* Corresponds to the number of hazardous substances identified as common within databases – i.e. between the SPIN and ECHA databases. Number of potential relevant substances within the full extract of the ECHA lists was 15,150.

5.3 SELECTING DANGEROUS SUBSTANCES

5.3.1 Results from the expert evaluations

The final cross-tabulation of substances across industries, delivered to the experts, included 142 unique substances relevant to one or more of the 26 identified industries, for a total of 319 entries. As described in section 3.1.5 this table was provided to the experts who rated the substances based on their importance according to the established criteria. Overall, the consensus (i.e. final) experts' evaluations equalled or exceeded a score of 5 in 165 instances, and a score of 6 in 115 instances across 24 of the 26 industries included suggesting an impracticably large set of substances. However, only 19 combinations of substances across industries received an overall score ≥8, and these were distributed only across 11 of the identified industries. This was considered to provide a viable list for further selection. An overview of the final (i.e. consensus) outcomes of the experts rating is provided in Table 6, and a copy of the table including all final evaluations is provided as an online appendix (Appendix 3) to the present report.

Table 6. Frequency distribution of substances in the final list across industries and overall ratings assigned by the experts.

NACE v2.2 code (2-digit)	Description of NACE code	Number of substances							
		Total	Overall expert score						
			3	4	5	6	7	8	9
A02	Forestry and logging industry	7	0	2	1	1	1	0	2
B08	Other mining and quarrying industry	4	1	1	1	1	0	0	0
C15	Manufacture of leather and related products industry	8	5	2	0	1	0	0	0
C16	Manufacture of wood and of products of wood and cork, except furniture industry	6	3	2	0	0	1	0	0
C18	Printing and reproduction of recorded media	4	1	2	0	0	0	1	0
C19	Manufacture of coke and refined petroleum products	12	1	1	2	8	0	0	0
C20	Manufacture of chemicals industry	46	21	4	7	12	2	0	0
C22	Manufacture of rubber and plastic products	18	8	1	4	0	5	0	0
C23	Manufacture of other non-metallic mineral products	4	2	0	0	1	0	0	1
C24	Manufacture of basic metals	7	2	1	0	2	0	1	1
C25	Manufacture of fabricated metal products, except machinery and equipment industry	15	6	2	1	3	3	0	0
C28	Manufacture of machinery and equipment n.e.c.	4	2	0	0	1	1	0	0

NACE v2.2 code (2-digit)	Description of NACE code	Number of substances							
		Total	Overall expert score						
			3	4	5	6	7	8	9
C30	Manufacture of other transport equipment	4	2	0	1	1	0	0	0
C31	Manufacture of furniture	9	4	1	3	1	0	0	0
C33	Repair and installation of machinery and equipment	3	1	0	1	0	1	0	0
E38	Waste collection, treatment and disposal activities	5	0	0	0	0	3	2	0
F41	Construction of buildings	10	4	0	2	1	1	0	2
F42	Civil engineering	3	0	0	1	1	0	0	1
F43	Specialised construction activities	16	7	1	4	3	0	0	1
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles industry	79	24	7	14	27	3	3	1
H50	Water transport	2	0	0	2	0	0	0	0
M75	Veterinary activities	6	0	0	3	1	0	2	0
N81	Services to buildings and landscape activities	27	13	4	2	6	1	1	0
Q86	Human health activities	10	6	1	1	2	0	0	0
Q87	Residential care activities	6	4	1	0	1	0	0	0
Q96	Personal service activities	4	3	1	0	0	0	0	0
	Total	**319**	**120**	**34**	**50**	**74**	**22**	**10**	**9**

5.3.2 Substance selection and the Level 1 Dangerous Substance Data Summary Sheets

An overview of all combinations of substances and industries that received an overall expert score of ≥6 is provided in Table 7. There are 115 such combinations in the table, corresponding to approximately 48% (n=68) of all the unique substances identified in Task 1. Task 1 Data Summary Sheets were developed for each of these 68 substances, with the decision to focus on them driven mainly by the increased logistics to cover all 142 substances initially identified. The resulting Data Summary Sheets are provided in Appendix 4.

Table 7. List of substances with overall expert scores above or equal to 6 per industry.

Nace	Industry name	Substance name (CAS num)			
		Score 9	Score 8	Score 7	Score 6
A02	Forestry and logging	- Pesticides and fungicides (NA) - Wood dust (NA)		- Lyme borreliosis - *Borellia spp*. (NA)	- Distillates (petroleum), solvent-dewaxed heavy paraffinic (64742-65-0)
B08	Other mining and quarrying				- Distillates (petroleum), solvent-dewaxed heavy paraffinic (64742-65-0)
C15	Manufacture of leather and related products				- 2,6-di-tert-butyl-p-cresol (128-37-0)
C16	Manufacture of wood and of products of wood and cork, except furniture			- Formaldehyde (50-00-0)	
C18	Printing and reproduction of recorded media		- Solvents (Several CAS)		
C19	Manufacture of coke and refined petroleum products				- Benzene (71-43-2) - Distillates (petroleum), solvent-dewaxed heavy paraffinic (64742-65-0) - Distillates (petroleum), hydrotreated light (64742-47-8) - Distillates (petroleum), solvent-refined heavy paraffinic (64741-88-4) - Naphtha (petroleum), hydrotreated heavy (64742-48-9) - Naphthalene (91-20-3) - Solvent naphtha (petroleum), heavy arom (64742-94-5) - Solvent naphtha (petroleum), light arom (64742-95-6)
C20	Manufacture of chemicals			- Metal Zinc (powder) (7440-66-6) - Titanium dioxide (13463-67-7)	- Cyclohexane (110-82-7) - Distillates (petroleum), hydrotreated heavy naphthenic (64742-52-5) - Distillates (petroleum), hydrotreated light (64742-47-8) - Distillates (petroleum), solvent-dewaxed heavy paraffinic (64742-65-0) - Naphtha (petroleum), hydro-desulfurized heavy (64742-82-1) - Naphtha (petroleum), hydrotreated heavy (64742-48-9)

Nace	Industry name	Substance name (CAS num)			
		Score 9	Score 8	Score 7	Score 6
					- Naphtha (petroleum), hydrotreated light (64742-49-0) - Solvent naphtha (petroleum), heavy arom. (64742-94-5) - Solvent naphtha (petroleum), light arom.(64742-95-6) - Solvent naphtha (petroleum), medium aliph.(64742-88-7) - Toluene (108-88-3) - Xylene (1330-20-7)
C22	Manufacture of rubber and plastic products			- Carbon Black (1333-86-4) - Styrene (100-42-5) - Talc ($Mg_3H_2(SiO_3)_4$) (14807-96-6) - Titanium dioxide (13463-67-7) - Xylene (1330-20-7)	-
C23	Manufacture of other non-metallic mineral products	- Mineral dust containing crystalline silica*			- Aluminium oxide (1344-28-1)
C24	Manufacture of basic metals	- Cadmium, chromium, lead, arsenic etc- i.e. Heavy metals (NA)	- Nickel (7440-02-0)		- Nitric acid (7697-37-2) - Sulphuric acid (7664-93-9)
C25	Manufacture of fabricated metal products, except machinery and equipment			- Chromium trioxide (1333-82-0) - Formaldehyde (50-00-0) - Solvent naphtha (petroleum), light arom. (64742-95-6)	- Hydrogen chloride (7647-01-0) - Nitric acid (7697-37-2) - Sulphuric acid (7664-93-9)
C28	Manufacture of machinery and equipment n.e.c.			- Solvent naphtha (petroleum), light arom. (64742-95-6)	- Xylene (1330-20-7)
C30	Manufacture of other transport equipment				- Solvent naphtha (petroleum), light arom. (64742-95-6)
C31	Manufacture of furniture				- Formaldehyde (50-00-0)
C33	Repair and installation of			- Solvent naphtha	

Nace	Industry name	Substance name (CAS num)			
		Score 9	Score 8	Score 7	Score 6
	machinery and equipment			(petroleum), light arom. (64742-95-6)	
E38	Waste collection, treatment and disposal activities		- Fungi and fungal spores (most importantly Aspergillus Fumigatus, Aspergillus flavus) - Microbial cell wall agents, mostly Endotoxins	- Chemical agents, mainly benzene and solvents (i.e. turpentine, xylene, toluene, acetone etc.) - Infectious agents mainly Salmonella and Hepatitis, HIV and haemorrhagic viruses. - Cadmium, chromium, lithium, arsenic, and lead (i.e. Heavy metals)	
F41	Construction of buildings	- Mineral dust containing crystalline silica* - Asbestos (12001-29-5, 12172-73-5, 12001-28-4, 77536-68-6, 77536-66-4, 77536-67-5)		- Synthetic amorphous silica (112926-00-8; registered as Silicon dioxide in ECHA)	- Xylene (1330-20-7)
F42	Civil engineering	- Mineral dust containing crystalline silica*			- Xylene (1330-20-7)
F43	Specialised construction activities	- Mineral dust containing crystalline silica*			- Asbestos (12001-29-5, 12172-73-5, 12001-28-4, 77536-68-6, 77536-66-4, 77536-67-5) - Xylene (1330-20-7) - Hydrogen chloride (7647-01-0)
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	- Lubricating oils (petroleum), C24-50, solvent-extd., dewaxed, hydrogenated	- 3-Isocyanatomethyl-3,5,5-trimethylcyclohexyl isocyanate,	- 4,4'-methylenediphenyl diisocyanate (101-68-8) - Methyl methacrylate	- Acetone (67-64-1) - Alkanes, C11-15-iso-(90622-58-5) - Bisphenol (Epoxy Resin) (25036-25-3) - Diphenylmethandiisocyanate, isomers

Nace	Industry name	Substance name (CAS num)			
		Score 9	Score 8	Score 7	Score 6
		(101316-72-7)	oligomers (53880-05-0) - Stoddard solvent (8052-41-3) - Sulphuric acid (7664-93-9)	(80-62-6) - Naphtha (petroleum), hydrodesulfurized light, dearomatized (92045-53-9)	and homologues (9016-87-9) - Distillates (petroleum), hydrotreated heavy naphthenic (64742-52-5) - Distillates (petroleum), hydrotreated heavy paraffinic (64742-54-7) - Distillates (petroleum), hydrotreated light (64742-47-8) - Distillates (petroleum), hydrotreated light naphthenic (64742-53-6) - Distillates (petroleum), hydrotreated light paraffinic (64742-55-8) - Distillates (petroleum), solvent-dewaxed heavy paraffinic (64742-65-0) - Distillates (petroleum), solvent-refined heavy paraffinic (64741-88-4) - Hexamethylene diisocyanate, oligomers (28182-81-2) - Hydrocarbons, C3-4-rich, petroleum distillate (68512-91-4) - Lubricating oils (74869-22-0) - Lubricating oils (petroleum), C15-30, hydrotreated neutral oil-based (72623-86-0) - Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based (72623-87-1) - Lubricating oils (petroleum), C20-50, hydrotreated neutral oil-based, high-viscosity (72623-85-9) - Naphtha (petroleum), hydrodesulfurized heavy (64742-82-1) - Naphtha (petroleum), hydrotreated heavy (64742-48-9) - Naphtha (petroleum), hydrotreated light (64742-49-0) - Propane-1,2-diol (57-55-6) - Quartz (SiO_2) (14808-60-7)

Nace	Industry name	Substance name (CAS num)			
		Score 9	Score 8	Score 7	Score 6
					- Residual oils (petroleum), solvent-dewaxed (64742-62-7) - Solvent naphtha (petroleum), heavy arom. (64742-94-5) - Solvent naphtha (petroleum), light arom. (64742-95-6) - Solvent naphtha (petroleum), medium aliph. (64742-88-7) - Talc (Mg3H2(SiO3)4) (14807-96-6)
H50	Water transport				
M75	Veterinary activities		- Allergens incl. animal allergens - i.e. bovine, swine, cat and dog (NA) - Microbial cell wall agents, mostly Endotoxins (NA)		- Ringworm / Dermatophytes (NA)
N81	Services to buildings and landscape activities		- Ammonia, aqueous solution (1336-21-6)	- Quaternary ammonium compounds, benzyl-C12-16-alkyldimethyl, chlorides (68424-85-1)	- Benzyl alcohol (100-51-6) - D-Glucopyranose, Oligomeric, C10-16(even numbered) Alkyl Glycosides (110615-47-9) - Distillates (petroleum), hydrotreated light (64742-47-8) - Hydrogen chloride (7647-01-0) - Naphtha (petroleum), hydrodesulfurized heavy (64742-82-1) - Naphtha (petroleum), hydrotreated heavy (64742-48-9) - Propane-1,2-diol (57-55-6)
Q86	Human health activities				- Hydrogen chloride (7647-01-0) - Xylene (1330-20-7)
Q87	Residential care activities				- Xylene (1330-20-7)

*Also referred to as Respirable Crystaline Silica (RCS) or quartz (CAS num: 14808-60-7) which is the most common form.

5.3.3 Substance selection for campaign recommendations and the Level 2 Dangerous Substance Data Summary Sheets

Table 8 presents the 15 most important substances as rated by the experts (i.e. those assigned overall scores ≥8) for the 26 industries included. The assigned overall score and the involved industries are also shown.

Table 8. List of combinations of substances and industries for which experts assigned an overall score ≥8.

Substance name	CAS num	Overall score	Industry (NACE code)
Cadmium, chromium, lead, arsenic etc - i.e. Heavy metals		9	- Manufacture of basic metals (C24)
Pesticides and fungicides		9	- Forestry and logging (A02)
Wood dust		9	- Forestry and logging (A02)
Asbestos	12001-29-5, 12172-73-5, 12001-28-4, 77536-68-6, 77536-66-4, 77536-67-5	9	- Construction of buildings (F41)
Mineral dust containing crystalline silica	14808-60-7 (for Quartz)*	9	- Construction of buildings (F41) Civil engineering (F42) Specialised construction activities (F43) - Manufacture of other non-metallic mineral products (C23)
Lubricating oils (petroleum), C24-50, solvent-extd., dewaxed, hydrogenated	101316-72-7	9	- Wholesale and retail trade and repair of motor vehicles and motorcycles (G45)
Nickel	7440-02-0	8	- Manufacture of basic metals (C24)
Fungi and fungal spores (most importantly Aspergillus Fumigatus, Aspergillus flavus)		8	- Waste collection, treatment and disposal activities (E38)
Microbial cell wall agents, mostly endotoxins		8	- Waste collection, treatment and disposal activities (E38) Veterinary activities (M75)
Solvents		8	- Printing and reproduction of recorded media (C18)
3-Isocyanatomethyl-3,5,5-trimethylcyclohexyl isocyanate, oligomers	53880-05-0	8	- Wholesale and retail trade and repair of motor vehicles and motorcycles (G45)
Stoddard solvent	8052-41-3	8	- Wholesale and retail trade and repair of motor vehicles and motorcycles (G45)
Sulphuric acid	7664-93-9	8	- Wholesale and retail trade and repair of motor vehicles and motorcycles (G45)
Allergens incl. animal allergens - i.e. bovine, swine, cat and dog		8	- Veterinary activities (M75)
Ammonia, aqueous solution	1336-21-6	8	- Services to buildings and landscape activities (N81)

*Quartz (CAS num 14808-60-7) is the most common form of crystalline silica.

The list of substance/industry combinations presented in Table 6, together with some additional detail concerning the individual expert scores (i.e. breakdown values for each of the established criteria described in section 3.1.5), and all the relevant Level 1 Data Summary Sheets, were fed back to the project team of exposure experts. Based on these data, experts were asked to identify the most important combinations of substances/industries included and to put forward proposals for those to be considered for analysis in the Level 2 Data Summary Sheets.

In general, there was good agreement between experts concerning those substances needing most attention, with recommendations put forward including the following:

a. Silica exposure among construction, mining, and manufacturing workers (possibly extendable to agriculture production and processing workers).
b. Asbestos exposure (both intentional and accidental) among construction and building workers.
c. Solvent exposure during printing both in the printing industry and in broader perspective.
d. Non-infectious biological agents particularly microbial cell wall and fungal agents in the waste recycling industry or more widely.
e. Wood dust in the forestry, construction, and manufacture of furniture industries.

Following liaison, experts agreed that final recommendations and Level 2 Data Summary Sheets should cover: a) the exposure to crystalline silica within the construction, mining, and manufacturing industries and b) the exposure to non-infectious bio-aerosols such as fungal and cell-wall microbial agents among workers, particularly in the waste management and recycling industries. The logic behind these recommendations is addressed in further detail in the following discussion section while the actual Level 2 Data Summary Sheets for these two substances are shown in sections 4.3.4 and 4.3.5 respectively.

5.3.4 Level 2 Dangerous Substance Data Summary Sheet for Crystalline silica/Quartz

Substance name:	**Crystalline silica (Quartz)**
CAS No. (if applicable):	**14808-60-7**
AKA / Synonyms / Sub-Groups:	Quartz (SiO_2), crystalline silica, Silica, silicium dioxide For a full list please look here
Substance identified from:	Expert assessment and for industry G45 (see below) the CLP Inventory
CLP classification and labelling	Classification: H302, H315, H319, H332, H335, H341, H350, H351, H370, H371, H372, H373, H413 GHS07, GHS08
Industries (NACE R2 code) for which the substance is relevant: **Substance uses**	Manufacture (MFR) of other non-metallic mineral products (C23), Construction of buildings (F41), Civil engineering (F42), Specialised construction activities (F43), Wholesale and retail trade and repair of motor vehicles and motorcycles (G45) Crystalline silica is a natural constituent of the earth's crust and a core constituent of sand and granite. It is generated as a by-product from (coal and diatomaceous earth) mining and (sand, granite and sandstone) quarrying etc[1]. Crystalline silica's most common form is quartz and the two terms are frequently used interchangeably. Other forms of crystalline silica are cristobalite and tridymite. Crystalline silica (quartz) is used in the glass industry for the production of (flat and container) silica glass; in the electronics industry for the manufacture of quartz oscillator and optical devices; for casting (sand mould, cores and parting sand) and finishing (e.g. abrasive on grinding wheels) in the foundry sector; as sandstone building stone, quartz sand and clay-containing bricks and tiles, sand and gravel-containing concrete in the construction (buildings and roads) industry; as fillers and extenders in the paint, pottery and plastics sectors; as a flux for smelting ores and welding operations; as a raw material in the chemical industry e.g. waterglass, ferrosilicon and silicon production; as a refractory liner in coke ovens, glass-melting tanks and furnaces, as an abrasive liner in ball mills and for cementing oil well liners when sinking shafts in the oil industry; as a sand filter in water purification units and in the manufacture of cultured quartz single crystals[2,3].
Health effects	Exposure can cause a variety of forms of damage to the respiratory system. Inhalation of quartz dust may cause irreversible lung damage even before any symptoms appear. Silicosis is a major risk from exposure to quartz dust. It causes nodules of scar tissue in the lungs and although the disease may take years to develop high exposures to quartz can cause an acute form of the disease. Silicosis is a slow progressive disease that usually develops over many years of exposure. The main symptoms are breathlessness, coughing and breathing difficulties. Acute silicosis can occur when persons are exposure to very high concentrations over months or years and can prove fatal within a short period of time.

[1] A. M. Donoghue, Occupational health hazards in mining: an overview, *Occupational Medicine* 2004;**54:**283–289
[2] M I Greenberg et al, Silicosis: A Review, Disease-a-Month, 2007, 394.
[3] C C Leung, Silicosis, Published Online April 24 2012, DOI:10.1016/S0140-6736(12)60235-9

	Persons who are exposed to conditions which may cause silicosis are at an increased risk of developing tuberculosis and lung cancer. These diseases may also develop even in the absence of silicosis. Exposure to quartz may also cause chronic obstructive pulmonary disease (COPD) which may cause breathlessness and a chronic cough. Persons who smoke and are exposed to quartz may be at increased risk[2,3].
Expert evaluation score(s)*	MFR of other non-metallic mineral products: 9 (3,3,3) Construction of buildings: 9 (3,3,3) Civil engineering:9 (3,3,3) Specialised construction activities: 9 (3,3,3) Wholesale & retail trade & repair of motor vehicles etc: 6 (3,2,1)
Employment characteristics **Total number of employed persons within the EU 28 (2015)**	MFR of other non-metallic mineral products: 1,209,457 Construction of buildings: 3,643,788 Civil engineering: 1,564,970 Specialised construction activities: 7,942,979 Wholesale & retail trade & repair of motor vehicles etc: 3,825,269
Trends in employment within industries (2008-2015)	Please, see figures 1 and 2

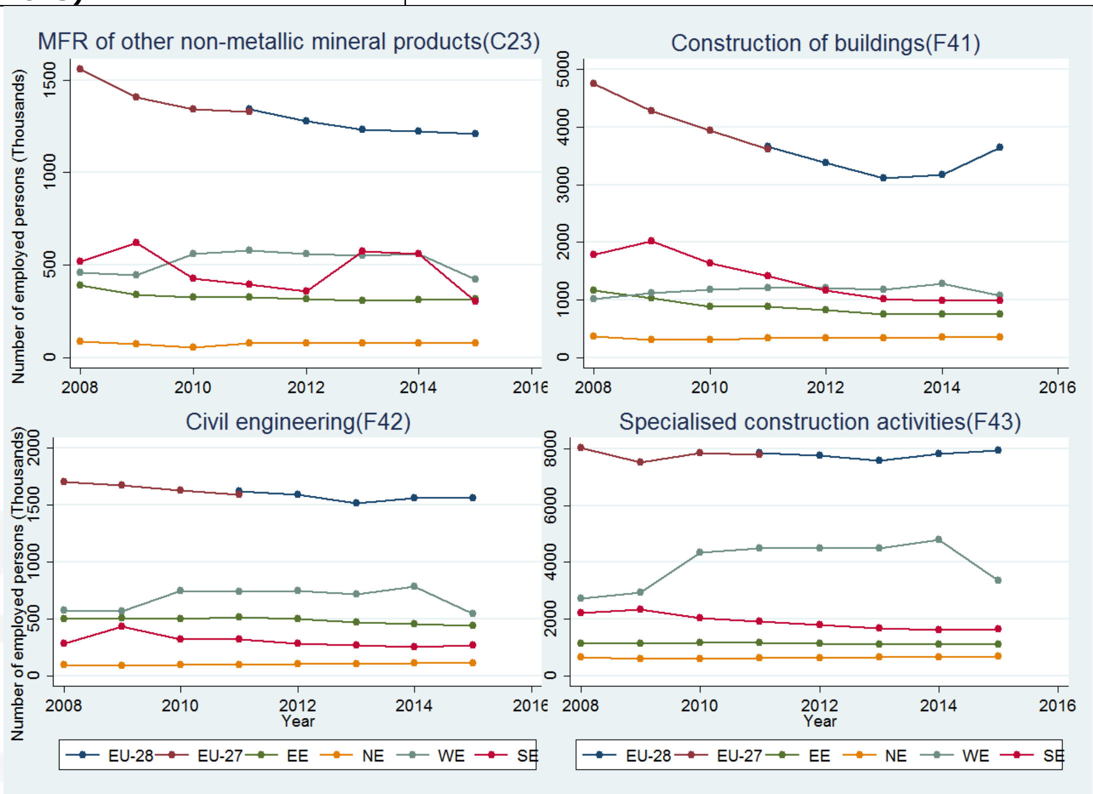

Figure 1 Trends in employment within industry (2008-2015) for geographical regions in Europe (EE=Eastern Europe, NE=Northern Europe, SE=Southern Europe, WE= Western Europe). Source of data: Structural business statistics (SBS).

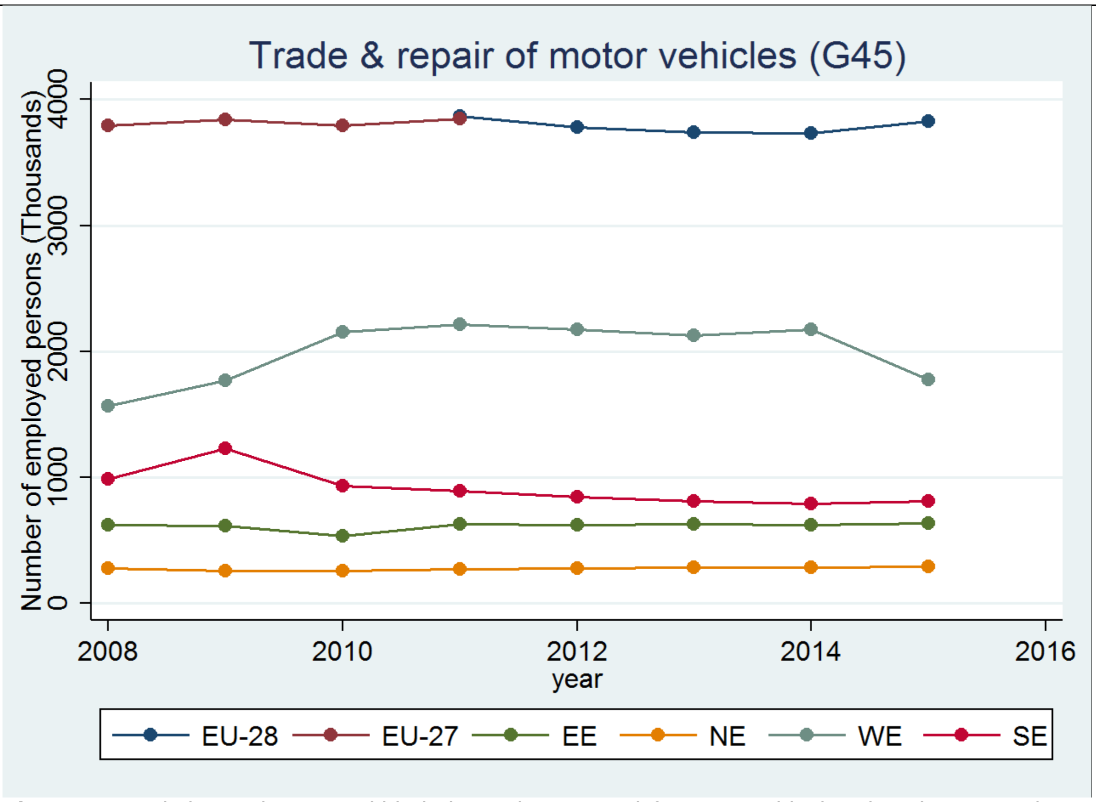

Figure 2 Trends in employment within industry (2008-2015) for geographical regions in Europe (EE=Eastern Europe, NE=Northern Europe, SE=Southern Europe, WE= Western Europe). Source of data: Structural business statistics (SBS).

Exposure characteristics

Note that where a number appears in parenthesis it is referring to a number of workers

Likely exposure scenarios

Exposure to crystalline silica, quartz may occur as a results of the release of dust whenever materials that contain the substance such as sandstone, concrete, tiles, granite, slate, bricks, limestones, and marbles are grinded, drilled, sanded, chiselled, chipped, fettled, cut, crushed and blasted as well as when the material is in dry powder form and it is mixed, shovelled or handled. Poor workplace hygiene may contribute further to the exposure due to surface building which may increase the potential for exposure during cleaning activities.

Typical levels and trends in exposure (when information available):

Table 1 provides an overview of exposure levels to respirable crystiline silica/quartz and respirable dust (sometimes used as an exposure surrogate) measured in typical jobs within the European construction, manufacturing of mineral products and mining industries. Measurement data from studies published after 2000 (non-exhaustive list) involving long-term and full-shift monitoring are included. More detailed overviews of ranges of measured exposure concentrations related to tasks and historical measurements can be found in previously published studies[4;5;6].

Table 1. Overview (non-exhaustive list) of results from European studies of exposure to respirable dust and respirable crystalline silica/ quartz within the construction and affiliated mining and manufacturing industries.

Industrial sector and job	Respirable dust (mg/m^3)			Respirable crystaline silica/quartz (mg/m^3)		
	Range of means	Range of individual concentrations	Ref	Range of means	Range of individual concentrations	Ref.
Quarries						
Drillers	1.12	0.2-12.00	7	0.11	<LOD-3.30	7
Drivers/mobile	0.48	<LOD-54.90	7	0.04	<LOD-0.72	7

plant operators						
Crushers and screens	1.11	<LOD-367.29	7	0.17	<LOD-3.40	7
Ancillary plant operators	0.84	<LOD-554.0	7	0.06	<LOD-0.83	7
Baggers and fillers	0.75	0.04-14.53	7	0.12	<LOD-0.57	7
Weighbridge attendants	0.29	<LOD-4.79	7	0.02	<LOD-0.56	7
Maintenance workers	0.81	0.03-240.20	7	0.06	<LOD-4.50	7
Supervisors and miscellaneous	0.49	<LOD-32.64	7	0.05	<LOD-0.56	7
Overall	0.48-1.11	<LOD-554.00	7	0.02-0.17	<LOD-4.50	7
Construction						
Bricklayer	0.22	0.04-0.59	8	0.02	0.01-0.04	8
Carpenter	0.22	0.03-4.67	8	0.02	0.01-0.09	8
Recess drilling, concrete drilling	0.86-3.1	<LOD-18.9	8;9;10	0.2-0.7	<LOD-6.9	8;9;10
Pointing, grinding mortar	2.4	0.5-8.0	10	0.35	0.09-1.6	10
Pointing	0.27-3.43	0.14-17.04	8;9	0.002-0.18	0.002-0.8	8;9
Demolition	1.17-10.8	0.09-298.8	8;9;10	0.12-1.1	<LOD-6.9	8;9;10
Building inner wall	1.5-2.1	0.2-10.6	9;10	0.04	<LOD-0.2	9;10
Site cleaners	0.58	0.14-2.5	10	0.02	0.002-0.1	10
Bystanders (carpenters and gluers)	0.19	0.14-0.3	10	0.004	0.002-0.02	10
Overall	0.88-5.2	<LOD-298.8	8;9;10	0.1-0.5	<LOD-35.9	8;9;10
Stonemasonry						
Restoration				0.05-0.7	<LOD-6.00	11
Concrete manufacturing						
Tile making	1.03-1.04		12	0.09-0.11		12
Brickmaking	0.34-0.72		12	0.03-0.05		12
Transport	0.64		12	0.06		12
Prefab	0.38-0.79		12	0.02-0.04		12
Maintenance	0.31-0.74		12	0.01-.048		12
Sewer drains	0.5		12	0.04		12
Overall	0.60-0.63		12	0.04 -0.5		12

Ref=reference; LOD=Limit of detection

Several studies have provided evidence for a reduction in workers levels of exposure to silica through the years. Mean concentrations of quartz measured for Swedish granite crushers (45) were observed to fall from 0.21 mg m^{-3} (before 1976) to 0.18 mg m^{-3} (between the years of 1976-1988)[6;13]. A large cross industry study of mostly European measurements (23,640) reported a 6% annual decline in levels of respirable crystalline silica within the period 1976 to 2009[14]. In UK quarries an annual reduction of 4% was reported for quartz exposure using measurements (2,846) collected between 1984 and 2003[11]. It should be mentioned however that in the latter two studies results may be influenced by the assumption of linearity (i.e. that levels decline by an equivalent proportion each year) in the estimated trends in exposure.

Source/s of exposure data

[4]Sauve JF, Beaudry C et al. (2013)Silica exposure during construction activities: Statistical modelling of task-based measurements. Ann Occup Hyg, 75(4):432-443.

[5]Occupational Safety and Health Administration. (2016). Occupational Exposure to Respirable Crystalline Silica. Final rule. Federal register, 81(58), Docket No. OSHA–2010–0034.

[6]Hoet P, Desvalles L et al. (2017) Do current OELs for silica protect from obstructive lung impairment? A critical review of epidemiological data.

[7]Creely K, van Tongeren M et al. (2006) Trends in inhalation exposure Mid 1980s until present. HSE Research report 460.Sudbury,UK

[8]Van Deurssen E, Pronk A et al. (2014) Quartz and respirable dust in the Dutch construction industry: A baseline exposure assessment as part of a multidimensional Intervention Approach.

	[9]Lumens MEFL, Spee T. (2001) Determinants of Exposure to Respirable Quartz Dust in the Construction Industry. Ann Occup Hyg, 45 (7): 585-595. [10]Nij ET, Hohr D et al. (2004) Variability in quartz exposure in the construction industry: Implications for assessing exposure-response relations. J Occup Environ Hyg, 1: 191-198 [11]Healy CB, Coggins MA et al. (2014) Determinants of respirable crystalline silica exposure among stoneworkers involved in stone restoration work. Ann Occup Hyg 2014, 58(1):6-18. [12]Meijer E1, Kromhout H et al. (2001) Respiratory effects of exposure to low levels of concrete dust containing crystalline silica. Am J Ind Med, 40(2):133-40. [13]Malmberg P, Hedenstrom H et al. (1993) Changes in lung function of granite crushers exposed to moderately high silica concentrations: a 12 year follow-up. Br Ind Med, 50: 726-731. [14]Peters S, Vermeulen R et al. (2011) Modelling of occupational respirable crystalline silica exposure for quantitative exposure assessment in community-based case-control studies. J Environ Monit, 13(11):3262-8.
Production/use characteristics **Trends in amounts used or manufactured:**	Please, see figures 3 and 4

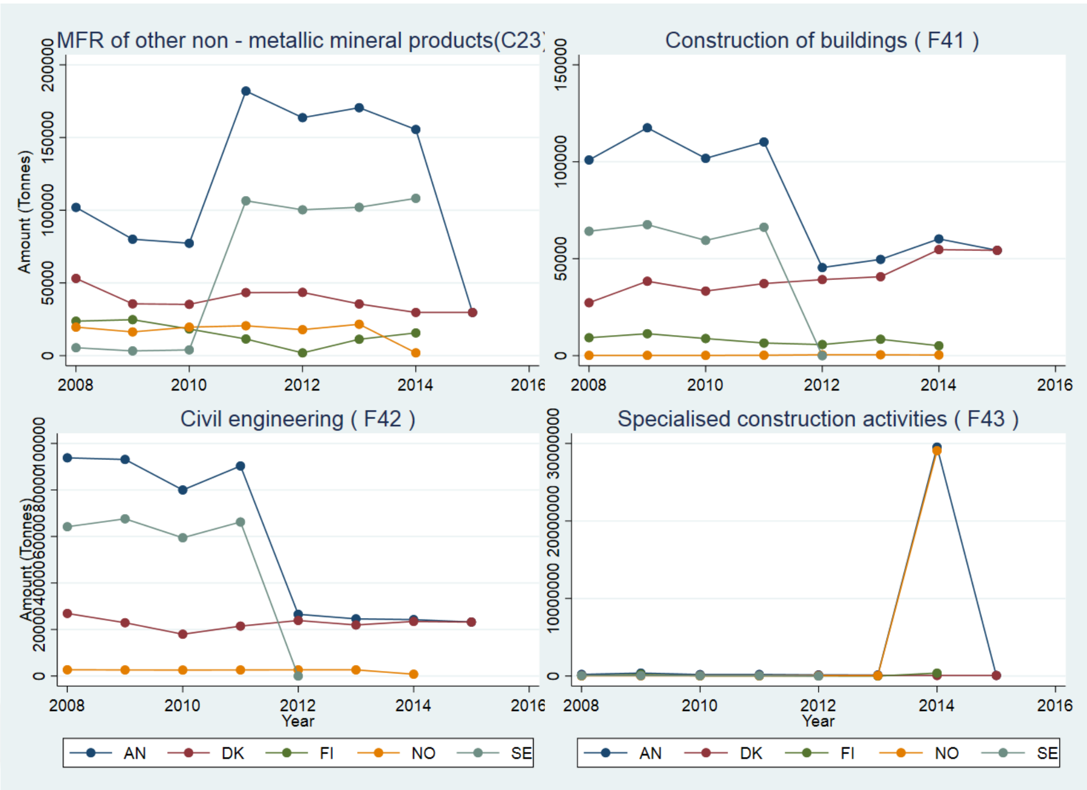

Figure 3 Trends in amounts used within industries (2008-2015) in Nordic countries (AN=All Nordic countries, DK=Denmark, FI=Finland, NO=Norway, SE=Sweden. Source of data: Substances in Preparations in Nordic Countries (SPIN) database

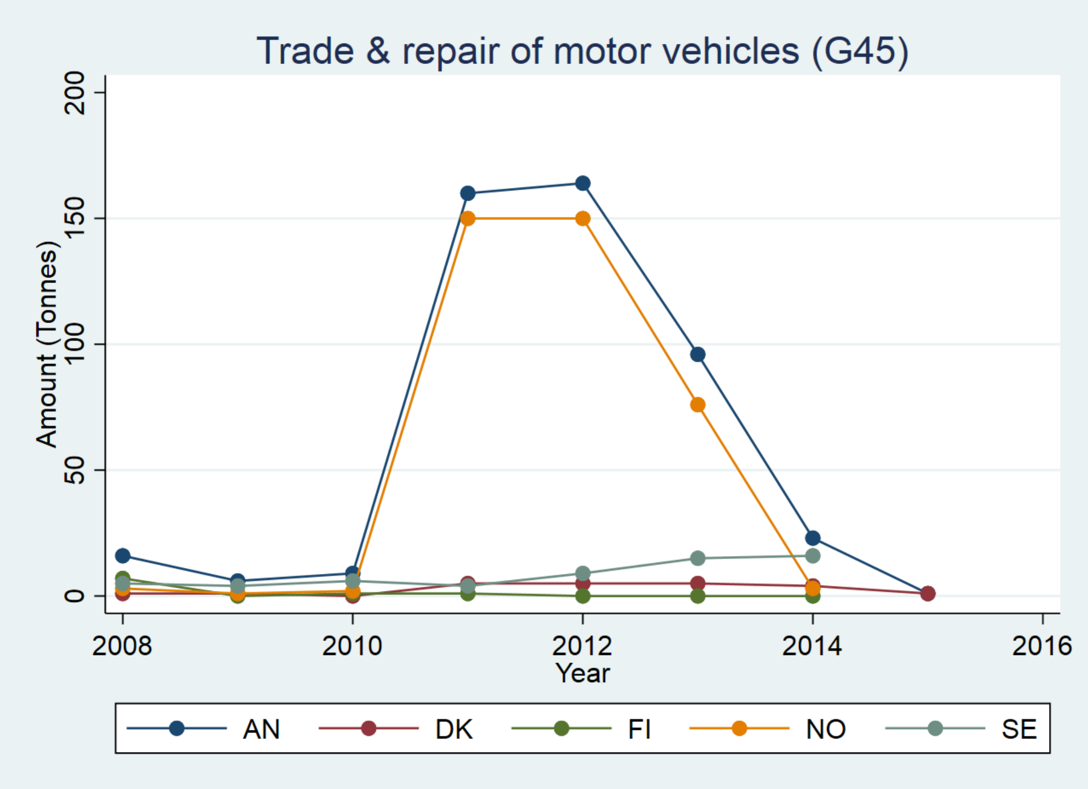

Figure 4 Trends in amounts used within industries (2008-2015) in Nordic countries (AL=All Nordic countries, DK=Denmark, FI=Finland, NO=Norway, SE=Sweden. Source of data: Substances in Preparations in Nordic Countries (SPIN) database

Comments and observations	*Employment development* From the available data it is apparent that little development occurs within most of the five industries reviewed. However, for the manufacturing of non-metallic mineral products and the building construction industries there seems to be a decline in numbers of employees following 2008 likely as a result of increased automation for the former industry and decreased construction activities amid the 2008 economic crisis for the latter industry. However, following economic recovery in EU countries in more recent years, employment in construction appears to be rising again. *Quantitative development* Since no data are available for process-generated amounts of crystalline silica (i.e. those generated because of abrasion, combustion, physical or chemical degradation of the material) the present assessment accounts only for changes in amounts used in workplaces and processes where crystalline silica/quartz is intentionally used as a substance within the manufacturing process. The available SPIN data (Figures 2 and 3) suggest potential increases within certain countries particularly for the manufacturing of non-metallic mineral products and the building construction industries. However, overall these data do not seem sufficient to suggest strong increases in amounts of manufacturing/ use. *General exposure levels in different sectors or tasks* From the results summarised in the exposure characteristics section and Table 1 it is apparent that levels of exposure within these industries have declined overthe years, mostlikely because of improved technologies, awareness and exposure control approaches. However, the summarised measured levels of exposure frequently exceed the recently proposed EU commission occupational limit (OEL) of 0.1 mg/m^3 (long-term exposure) for respirable crystalline silica dust (http://europa.eu/rapid/press-release_MEMO-16-1655_en.htm). This is true for all industries summarised within the present work. Currently established occupational exposure limits for quartz dust in

	EU countries range between 0.025 and 0.15 mg/m^3. **Simple summary of findings:** Quantitative development: Small increases in amounts of quartz used observed for some countries but trends seem neutral overall. General exposure levels in different sectors or tasks: Exposure levels appear to have declined but they still appear to exceed recommended or established OEL values in most cases and industries. Critical uses with high exposures: Construction industries (NACE codes F41, F42 and F43) due to the frequency of exposure occurrence and the large numbers of workers involved and potentially affected. Note that the substance was not identified as a hazard on CLP lists within the MFR of other non-metallic mineral products (C23), Construction of buildings (F41), Civil engineering (F42), and Specialised construction activities (F43) industries. Data extraction was performed during mid-April 2017. * 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. The individual scores for each component (a,b,c) are provided inside the parenthesis.

5.3.5 Level 2 Dangerous Substance Data Summary Sheet for bioaerosols in the waste management industry

Substance name:	**Bio-aerosols, non-infectious**
CAS No. (if applicable):	**Not applicable**
AKA / Synonyms / Sub-Groups:	Mainly refers to fungi, fungal spores, and microbial cell wall agents. Most important are endotoxins, glucans, (1,3)-beta-D-glucan, extracellular polysaccharides, ergosterol, peptidoglycans, muramic acid, and the fungi *Aspergillus Fumigatus, Aspergillus flavus, Stachybotrys atra, Fusarium spp.*
Substance identified from:	Expert assessments
CLP classification and labelling	Non classified
Industries (NACE R2 code) for which the substance is relevant:	Waste collection, treatment and disposal activities (E38)
	Organic waste streams have become a resource for both material and energy production. These organic waste streams may contain non-infectious bio-aerosols present in solid domestic and industrial/agricultural food (and its packaging), as well as in paper and garden, wood offcuts, clinical, (hospital, care home, medical centre), parks, sewage sludge and agricultural (animal manure, crop (cereal and vegetable) residues. Organic municipal waste also occurs in liquid form (vegetable oils, slurry, silage effluent)[1]. Waste management can be considered as a 4 step process: - 1. waste collection/transport (as uplift from residential or business premises, conveyance to and off-loading at a waste facility) as the collection of non-hazardous (H38.11) or of hazardous (H38.12) waste; 2. waste pre-treatment (sorting) as the recovery of sorted material (H38.32); 3. waste treatment of non-hazardous waste (H38.21) or of hazardous (H38.22) waste using environmentally sustainable (recycling, reuse & composting) or traditional (landfill & incineration) approaches; and 4. final disposal of non-hazardous waste (H38.21) or of hazardous (H38.22) waste by landfill or recycling e.g. agricultural/ industrial waste and sewage sludge used as soil amendments or composted agricultural and garden waste used as biomass fuel in power plants [2,3]. Contact with these waste streams (including dead non-infectious bio-aerosols of microorganisms) during composting, and to some extent landfilling of organic waste-contaminated packaging, can lead to inhalation exposure, which produces immunological or toxic responses[1]. (Incineration has been reported as a less suitable technique for treating organic material[3].)
Health effects	Exposure to microbial cell wall and fungal substances may result in a broad range of health symptoms which could depend on the exact composition of the substance involved. Both acute and chronic effects could be the result of exposure to these agents[4]. Acute symptoms linked to such exposures include wheezing, dyspnoea, irritation of the nose and throat, chest tightness, dry cough, fever, headache, and acute

[1] L. Rushton, Health hazards and waste management, British Medical Bulletin 2003; 68, 183–197.
[2] I. M. Wouters, Overview of Personal Occupational Exposure Levels to Inhalable Dust, Endotoxin, b(1!3)-Glucan and Fungal Extracellular Polysaccharides in the Waste Management Chain, Ann. Occup. Hyg., 2006, 50(1), 39–53.
[3] L. Giusti, A review of waste management practices and their impact on human health, Waste Management, 2009, 29, 2227–2239.
[4] Douwes J, Thorne P *et al.* Bioaerosol health effects and exposure assessment: progress and prospects. *Ann Occup Hyg* 2003;47:187–200.

	airway obstruction and inflammation. Very high levels of exposure may cause a series of flu-like symptoms called organic dust toxic syndrome (ODTS) and have been shown to increase the risk of chronic respiratory diseases, including extrinsic allergic alveolitis, chronic bronchitis, accelerated lung function decline, asthma and asthma-like syndrome [4;5;6;7]. The most well studied substance having the most well documented health effect capability is endotoxin. Besides the above symptoms, endotoxin can also simply increase disease severity by causing lung function adverse effects and promoting inflammatory responses[4;5;6;7]. Positive associations between endotoxin and malignant disease such as nasopharyngeal cancers have also been reported among cotton workers[8;9].
Expert evaluation score(s)*	Waste collection, treatment and disposal activities: 8 (3,3,2)
Employment characteristics	
Total number of employed persons within the EU 28 (2015)	Waste collection, treatment and disposal activities: 918,177
Trends in employment within industries (2008-2015)	Please see figure 1

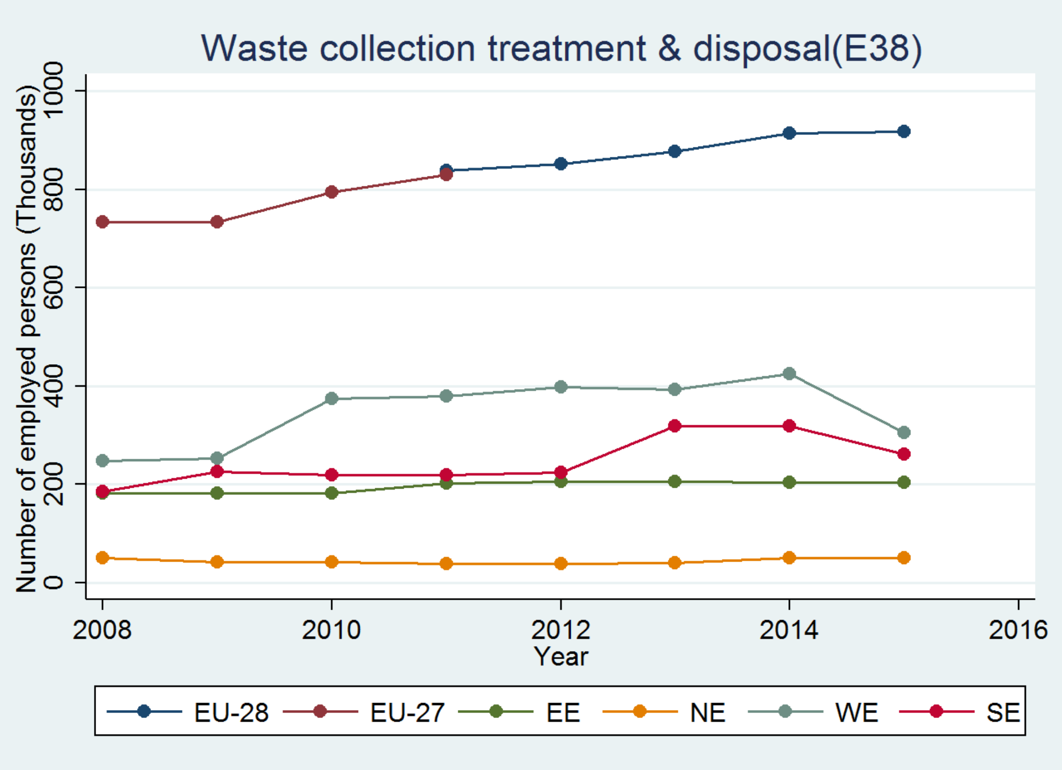

Figure 1 Trends in employment within industry (2008-2015) for geographical regions in Europe (EE=Eastern Europe, NE=Northern Europe, SE=Southern Europe, WE= Western Europe). Source of data: Structural business statistics (SBS).

Exposure characteristics **Likely exposure scenarios**	Recycling and composting success rates depend on the segregation of municipal solid waste streams for uplift (source separation) and during the sorting process (centralised separation). The organic stream is often inconsistent, varying in size and moisture and nutrient content, ranging from leaves, grass, vegetable peelings to food scraps and soiled paper. Composting often relies on centralised

[5] Sigsgaard T, Bonefeld-Jorgensen EC, et al. Microbial cell wall agents as an occupational hazard. Toxicol Appl Pharmacol 2005;207:310–9.
[6] Eduard W. Fungal spores: a critical review of the toxicological and epidemiological evidence as a basis for occupational exposure limit setting. Crit Rev Toxicol 2009;39:799–864.
[7] Douwes J. (1-->3)-Beta-D-glucans and respiratory health: a review of the scientific evidence. *Indoor Air* 2005;15:160–9.
[8] Fang SC, Mehta AJ, et al. Cotton dust, endotoxin and cancer mortality among the Shanghai textile workers cohort: a 30-year analysis. Occup Environ Med 2013;70:722–9.
[9] Li W, Ray RM, et al. Occupational risk factors for nasopharyngeal cancer among female textile workers in Shanghai, China. Occup Environ Med 2006;63:39–44.

	separation of mixed raw waste streams at a waste facility to remove inert and chemical contaminants e.g. the material recovery from wrecks (H38.31) or of sorted materials (H38.32) such as batteries & electronics for recycling. Manual separation is still widely used but some screening can be performed mechanically, magnetically or by air or wet classification methods. Once non-compostable material has been removed, the stream undergoes size reduction and homogenisation before it is ready for the longer aerobic biological decomposition by living organisms (bacteria, yeast and fungi) present in this environment). This process, with a residence time from days to months, is controlled by adjusting carbon and nitrogen, moisture, oxygen and temperature levels. Open windrow[4] and static piles are often outside (but can be roofed) and more closed (vertical/horizontal reactors and rotating drum) composting techniques are used. These employ natural (windrows) or forced (static piles, reactors & rotating drum) aeration and agitation (windrows[10], reactors & rotating drum). Skid steer loaders, front-end loader and excavator vehicles are routinely used to load and unload the plant (screens and composters etc.), for moving raw waste feedstock and materials, building windrows and static piles, agitating (turning) windrows and loading the finished compost product onto trucks[11]. Finished compost may also be packaged into individual containers on a bagging (and palletising) line or manually. A considerable level of manual intervention is typically required on a semi- and even on a fully automated bagging lines. Sampling and testing intermediate and finished compost and clearing up spills and leaks are largely carried out by hand. Thus, exposure to non-infectious bio-aerosols depends on the presence of organic material in the waste and can occur at any stage in the waste management process. As such, exposure may be truly occupational (e.g. arising during the active composting and stabilisation, curing and application of composted organic waste) or accidental (e.g. arising when sorting raw waste material for recycling).
Typical levels and trends in exposure (when information available):	For these agents, most exposure information related to personal airborne concentrations is available for endotoxins, glucans and fungal spores. Because of the increased cost for analytical determination of these agents, and the lack of established occupational exposure limits for them. The burden of exposure to these agents is frequently indirectly assessed by measuring exposure to "organic" dusts. An overview of measured airborne levels at a worker level (i.e. personal sampling) for these four substances (i.e. organic dust, endotoxin, glucans, and fungal spores) is provided in Tables 1 and 2. Studies on long-term and full-shift sampling among European workers in the waste collection, treatment and disposal industry, published after 2000 (non-exhaustive list), are included. More detailed overviews of ranges of measured exposure concentrations related to tasks and historical measurements can be found in previously published studies [11;12;13].

[10] N Wéry, Bioaerosols from composting facilities—a review, Front Cell Infect Microbiol 2014, 4;4:42.
[11] A Searl & J Crawford, Review of Health Risks for workers in the Waste and Recycling Industry. 2012, IOM report 611-00491
[12] Searl, A. Exposure-response relationships for bioaerosol emissions from waste treatment processes. Defra Project WR 0606 2008, Institute for Occupational Medicine for, UK.
[13] Pearson C, Littlewood E, et al. Exposures and health outcomes in relation to bioaerosol emissions from composting facilities: a systematic review of occupational and community studies Journal of Toxicology and Environmental Health, Part B 2015, 18.1: 43-69.

Table 1. Overview (non-exhaustive list) of results from studies of airborne dust and endotoxin levels within the waste collection, treatment and disposal sector.

Type of activity	Dust (mg/m^3)*			Endotoxin (EU/m^3)		
	Range of means	**Range of individual concentrations**	**Ref**	**Range of means**	**Range of individual concentrations**	**Ref**
Domestic waste collection, mixed waste						
Mixed tasks	0.37-1.1	<LOD-5	14;15	13-52	7-1810	14;15
Driver	0.3-6.3	0.4-16.0	15;16	16-360	15-1010	15;16
Loader	0.8-7.7	0.3-24.0	15;16	51-360	9-2279	15;16
Domestic waste collection, organic waste						
Mixed tasks	0.5	<LOD-3.6	15	33	9-422	15
Driver	0.7	<LOD-2.2	15	20	<LOD-69	15
Loader	0.4	<LOD-3.6	15	48	16-257	15
Domestic waste collection, residual waste						
Mixed tasks	0.3	<LOD-0.7	15	30	12-88	15
Driver	0.3	<LOD-1.5	15	30	8-172	15
Loader	0.6	<LOD-9.1	15	49	<LOD-7182	15
Compost facilities						
Mixed tasks	0.3-4.6	0.1-11	16;17	3-76	<LOD-324	16;17
Technician	1.2-2.4	0.5-7.6	15	108-661	24-3544	15
Bulldozer operator	0.3-1.2	<LOD-12.2	15	29-206	<LOD-8669	15
Operator	0.6-4.9	<LOD-130.7	15;16;18	61-1038	<LOD-37043	15;16;18
Sorter (Manual)	0.7	0.7-0.8	15	296	205-471	15
Office	0.3-0.8	0.1-1.1	15	6-175	3-183	15
Waste sorting and transferal, residual waste						
Mixed tasks	0.5	<LOD-12.6	19	23.1	2.0-461	19
Sorter (Manual)	0.3-8.3	<LOD-33.4	15;16;19	24-520	50-3536	15;16;19
Operator	6.1-7.3	42-10.3	15;16	200-320	159-684	15;16
Waste sorting and transferal, mixed /other waste						
Operator	1.2-2.7	0.5-7.9	15;16	36-160	16-200	15;16
Other tasks	0.5-3.8	<LOD-7.4	15;16	30-120	23-1040	15;16
Waste Landfill						
Operator	0.9	0.2-1.9	16	400	90-1200	16
Other tasks	0.3	0.11-0.6	16	380	90-1500	16

*inhalable and total fractions; Ref=reference; LOD=limit of detection

Table 2. Overview (non-exhaustive list) of results from studies of airborne glucan and fungal spore levels within the EU waste collection, treatment and disposal sector.

Type of environment	glucans (ng/m^3)			Fungal spores (10^3 CFU/ m^3 except when stated)		
	Range of means	**Range of individual concentrations**	**Ref**	**Range of means**	**Range of individual concentrations**	**Ref**
Domestic waste collection, mixed waste						
Any job	2.0-52	0.4-220	14	200x10^3	0-2000x10^3	14 (values in spores /m^3)
Driver	0.33-1.43	<LOD-4.79	15	30	06.2-61	16

Loader	0.6-1.60	<LOD-14.89	15	63	6.8-132	16
Domestic waste collection, organic waste						
Mixed job	2.18	<LOD-24.82	15			
Driver	1.43	<LOD-4.79	15			
Loader	1.60	<LOD-14.89	15			
Domestic waste collection, residual waste						
Mixed job	1.06	<LOD-5.88	15			
Driver	0.84	<LOD-5.95	15			
Loader	1.63	<LOD-30.75	15			
Compost facilities						
Mixed tasks				0.02	0-41	17 (values in spores /m^3)
Technician	3.43-4.85	1.03-53.23	15			
Bulldozer operator	0.36-1.76	<LOD-25.61	15			
Operator	0.48-4.93	<LOD-206.6	15	27	5.8-69	16
Sorting (Manual)	0.73	<LOD-1.34	15			
Office	<LOD-0.52	<LOD-0.62	15			
Waste sorting and transferal, residual waste						
Mixed tasks				50	0.1-2700	16;19
Sorter (Manual)				41-102	0.1-2600	16;19
Operator				126		16
Waste sorting and transferal, mixed /other waste						
Operator				16	11-26	16
Other tasks				12	5.4-19	16

Data on time-trends of bio-aerosols exposure are scarce. A recent study that modelled time trends in endotoxin exposure using 3,384 personal measurements mostly from workers of different industries in EU countries and Canada reported the overall levels of exposure to decline annually by almost 2%. The used database contained measurements collected between 1992 and 2008 with some sourcing from the waste management sector but no industry specific analysis was reported[20].

Source/s of exposure data

[14] Heldal KK, Halstensen AS, Thorn J, Eduard W, Halstensen TS. Airway inflammation in waste handlers exposed to bioaerosols assessed by induced sputum. European Respiratory Journal. 2003 Apr 1;21(4):641-5.

[15] Wouters IM, Spaan S, Douwes J, et al. Overview of personal occupational exposure levels to inhalable dust, endotoxin, beta(1-->3)-glucan and fungal extracellular polysaccharides in the waste management chain. Ann Occup Hyg 2006;50:39–53.

[16] Krajewski JA, Tarkowski ST, Cyprowski M, Szarapinska-Kwaszewska J, Dudkiewicz B. Occupational exposure to organic dust associated with municipal waste collection and management. International journal of occupational medicine and environmental health. 2002;15(3):289-301.

[17] Heldal KK, Barregard L, Ellingsen DG. Biomarkers of inflammation in workers exposed to compost and sewage dust. International archives of occupational and environmental health. 2016 Jul 1;89(5):711-8.

[18] Stagg S, Bowry A, Kelsey A, Crook B. Bioaerosol emissions from waste composting and the potential for workers' exposure. Health and Safety Laboratory. Health Safety Executive research report RR786. 2010.

[19] Schlosser O, Déportes IZ, Facon B, Fromont E. Extension of the sorting instructions for household plastic packaging and changes in exposure to bioaerosols at materials recovery facilities. Waste Management. 2015 Dec 31;46:47-55.

[20] Basinas I, Wouters IM, Sigsgaard T, et al. O46-4 Development of a quantitative job exposure matrix for endotoxin exposure in agriculture. Occup Environ Med 2016;73:A88.

Production/use characteristics	These substances are microorganisms or integral structural components of microorganisms and important constituents of the so-called 'organic dust' arising

	from the handling and processing of microbial, plant and animal originated material. Because of their process-generated nature these substances are not covered by the available databases on manufacturing and/or use volumes.
Trends in amounts used or manufactured:	Not applicable – process generated
Comments and observations	*Employment development* From the available data (Figure 1) it is apparent that there is clear growth in employment within the industry. This follows closely the increased societal and political demand towards zero waste which demands constant and increased recycling and re-use of products and materials. Due to this demand, the recycling industry has been steadily increasing in recent years with an expectation that this trend will continue further in the years to come. *Quantitative development* There are at this time no data available as these substances are process-generated. *General exposure levels in different sectors or tasks* From the results summarised in the exposure characteristics section and the Tables 1 and 2 above it is apparent that levels of exposure to these substances for waste industry workers is rather variable but generally high. There are no established health based limits values for most of these substances with the exception of endotoxin for which a Health Based Occupational Exposure Limit (HBROEL) of 90EU/m^3 has been proposed to be adapted by the Dutch and Nordic industries[21]. For fungal spores a lowest observed effect level (LOEL) of 10^5 spores/m^3 has been proposed[6]. These substances have very strong inflammatory capabilities causing a broad range of health symptoms and the summarised exposure levels frequently exceed limit values. It should be noted that besides bio-aerosols, waste handlers and recycling workers be exposed to a wide range of substances including Volatile Organic Compounds (VOC) and heavy metals. Exposures will depend largely on the material and type of waste handled. **Simple summary of findings:** Quantitative development: no data/neutral General exposure levels in different sectors or tasks: Very variable but frequently exceeding recommended health based exposure level. Critical uses with high exposures: Exposure are influenced by material presence and growth conditions differences between tasks and sub-sectors are rather small. The most likely important subs-sectors within the increasing workforce involved include materials recovery and the treatment and disposal of non-hazardous waste. * 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. The individual scores for each component (a,b,c) are provided inside the parenthesis.

[21]DECOS. Endotoxins: health based recommended exposure limit. A report of the Health Council of the Netherlands, publication no. 2010/04OSH. The Hague: : Health Council of the Netherlands 2010.

5.4 UPDATED LIST OF RELEVANT INFORMATION SOURCES

Besides the development and performance of the feasibility study described above, and as detailed on paragraph 3.1.7 of the methods section, we also sought to compile a list of useful potential information sources. An outline of the updated list provided initially by EU-OSHA is shown in Appendix 5, whereas Appendix 6 provides some further insight regarding substances covered by measurements in the identified human exposure databases.

6 DISCUSSION

The present project aimed to provide EU-OSHA with insight into developments in manufacturing, use and potential exposure levels of dangerous substances in EU workplaces within the period 2000 to 2015. It also aimed to examine the feasibility of establishing a sound method for the monitoring of those developments that may be utilised in similar exercises in the future. Merging databases that are (largely) publically available, with direct input from experts, we have elaborated an approach which seems capable of both monitoring these quantitative developments in relation to substance use and exposure, and of allowing the identification of dangerous substances relevant to the exposure and health of workers within specific industries. Application of the approach allowed the identification of 142 substances relevant to one or more of the 26 industries where exposure to dangerous substances was an important issue.

Through an assessment of the potential health risk and exposure importance for each of the 326 unique combinations of substances and industries we were able to identify the most important combinations and to analyse the quantitative developments regarding the population concerned and the production and use characteristics. The results provide a list of several different proposals (see section 4.3.3) of substance/ industry combinations to be considered as the top priorities for worker protection and EU-OSHA's upcoming 2018-19 "Healthy Workplaces Campaign".

Our final proposals, based on assessment by experts, were selected as exposure to:

a) crystalline silica within the construction, mining and manufacturing industries,
   and
b) non-infectious bio-aerosols such as fungal and cell-wall microbial agents among workers particularly on the waste management and recycling industries.

The selection of crystalline silica as a top priority substance mainly reflects its cross-industry nature and consequent large number of potentially affected workers, the lack of adequate exposure control in many of the involved workplaces and the severe consequences of exposures, both for the individual's health and at the broader societal/economic level. It has previously been estimated, as part of the SHECAN project, that in 2006 approximately 5,300,000 workers were exposed to respirable crystalline silica at their work, with an expected annual number of deaths from lung cancer attributable to respirable crystalline silica exceeding 5,000 for many decades to come (assuming stable trends in employment and exposure patterns)[14]. The data summarised in section 4.3.4 suggest that, despite a decline in annual levels of exposure over the last decades, the levels of exposure across-industry remain considerable and an increase in employment patterns within the construction sector is observed following 2013.

Construction is probably the most important industry for exposure to respirable crystalline silica, both in terms of exposed persons and level of exposure. It is notably not a part of the "European Network for Silica" and the Social Dialogue "Agreement on Workers' Health Protection Through the Good Handling and Use of Crystalline Silica and Products Containing it". The agreement was signed by the Employee and Employer European sectoral associations of 15 industrial sectors where exposure to silica is a potential issue, including the European federations of manufactures of Foundry, Cement, Precast Concrete, Ceramics, Mortar, Mines, Glass Fibre, Container Glass, Insulation, Expanded Clay, Natural Stones, Aggregates, Industrial Minerals, the Building, Automotive and Transport Glass association and the European trade union (industriALL). It aims for the minimisation of exposure to respirable crystalline silica at the workplace by applying a set of measures based on the principle of Good Working Practices and by increasing knowledge and awareness of the potential health effects of Respirable crystalline silica and the use of good practices. For the latter the network published a guide which has not yet been officially endorsed by the construction industry. Recently the US Occupational Safety & Health Administration (OSHA) introduced a permissible exposure limit (PEL) for long term (8-hour shift) exposure to respirable crystalline silica of 0.05 mg/m^3 to be implemented both in the construction and general industries.[15] In contrast, there is currently no European limit value established for respirable crystalline silica with summarised exposure results suggesting issues of compliance with suggestions made previously.

For the exposure of workers in the waste collection, treatment and disposal activities industry to non-infectious constituents of organic dusts (i.e. bioaerosols), selection was based on reasons that were slightly different to those for crystalline silica. Particularly, these substances have a strong pro-inflammatory and allergenic potential which, although largely non-life threatening, may lead to health conditions with severe economic and social consequences for both the individuals involved and society in total (e.g. by causing chronic obstructive pulmonary disease, allergy and asthma). They are a well-recognised and important hazard for waste and recycling workers[16] and, for most, there are currently no established occupational exposure limits. Information on exposure trends to these agents is also generally minimal whereas exposure, though broad in terms of jobs and sectors occurring, is very variable both in composition and levels of exposure (see section 4.3.5). The microbial origin and characteristics of these substances (e.g. self-replication for some) complicate exposure control and prevention in the workplace.

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[14] Cherrie JW, 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. Edinburg: Institute for Occupational Medicine. 2011

[15] https://www.osha.gov/silica

[16] Rushton L. Health hazards and waste management. British medical bulletin. 2003 Dec 1;68(1):183-97.

In addition, the recycling industry is relatively new so that several of the related occupations have not been officially described as job titles within editions of the International Standard Classification of Occupations prior to the most recent one (i.e. 2008). The introduction of legislation for waste management by the EU Commission in the mid to late 90's (Council Directive 99/31/EC) has led to sharp changes in the structure of the industry and a broad and consistent expansion of its recycling branch, both in terms of employment and output trends. [17] The growth of the industry further increases the challenges and risk regarding the health and safety of the workers involved. This reflects the exposure characteristics described above; the increased volumes of waste that need to be diverted from traditional landfill disposal to recycling; the large diversity in exposure substances involved; and, at least partly, to the introduction of new technologies and work-population dynamics.

6.1 STUDY LIMITATIONS

There are several issues that should be considered to put the methodology and results described above into perspective. To begin with, we applied a methodology that was largely data-driven in identifying substances of importance. However, when looking at the derived lists of dangerous substances across specific industries based on the analysis of the SPIN and ECHA substance list, it becomes evident that some important dangerous substances are missing from the final lists, either as a result of applied legislation, or because they are still not widely used or used in considerable (enough) amounts across the respective industries. Good examples of the former such substances are a) asbestos and b) carbon black.

Carbon black is a commonly used nanomaterial in the manufacturing of rubber materials (mainly tyres) and plastics and to a lesser extent inks. Approximately 70% of the total global carbon black production is used in the manufacturing of tyres and rubber; and the substance itself is classified by IARC as potentially carcinogenic. Asbestos on the other hand has historically been used in a broad range of materials for different applications including domestic use as well as use in the automotive, construction and shipyard industries. Since the establishment of its hazardous nature, asbestos use has declined and currently any production or new use/installation of material containing asbestos is prohibited across all EU countries. Consequently, any potential exposure due to the manufacturing and installation of new material is unlikely. Importantly however, the existing legislation allows any existing materials containing asbestos that are in good condition to remain intact. Such materials may include cement, flooring tiles, panels and roofing felts, insulation materials and spray coatings and reinforced plastics, which can commonly be found in buildings build or refurbished before the year 2000. As a consequence of the presence of asbestos in such environments, exposure may be relevant for workers within the construction industry (i.e. NACE codes F41; F42 and F43) who are performing repair or building refurbishments and handling ACMs. Workers may be informed or not about the presence of these materials, particularly in relation to domestic

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

properties for which an asbestos assessment and management plan is not a legal requirement.

Similar to the above, the SPIN and PRODCOM databases, including data on the volumes of production and use of chemicals within industries, do not cover dangerous substances that are process-generated or have a biological origin. These types of substances are also not covered by REACH and thus not included in the CLP inventory. Again, good examples of such substance are the non-infectious bio-aerosols within workers in the waste management and recycling industry – for reasons summarised above- and wood dust which is a classified carcinogenic, process-generated substance affecting large numbers of workers handling or processing wood within the construction, forestry, and manufacture of wood articles and furniture industries.

As part of our methodology we used expert judgement to identify the missing substances from our lists. However, as expert opinion is rather subjective and rather dependent on the particular expert's range of knowledge we cannot totally exclude the possibility that certain substances (including those with similar attributes to asbestos and carbon black as described above) may have been missed from our final lists. In addition, the expert's in-depth knowledge of the relevant exposures and associated conditions within a certain job or industry may potentially be a source of bias in the classification of substances on the basis of their health and exposure importance. Also, Combined with some clear logistic constraints (i.e. time scales and cost) we had to abstain from detailed qualitative evaluation based on mediating a consensus when disagreements between experts were encountered. Instead, to account for theses instances a rigorous second stage evaluation was applied where the scores input by the two experts were assessed and arbitrated by the third independent expert.

It should also be noted that only UK experts were involved in these substance evaluations and ratings; a characteristic which could potentially have impacted both on the assigned scores and the list of substances thus identified as important within the involved industries, due to a potential lack of detailed knowledge on the industries and exposure conditions in other EU countries. Although originally planned, it was not possible for EU-OSHA to source its own experts from different countries in the strict time-frame required to achieve the project's objectives.

These may add to the somewhat inevitable bias of a data driven approach whereby the substance selection process inherently favours those substances already possessing the appropriate (hazard or other) characteristics in their data attributes, as in the CLP Inventory.

Some issues associated with the content and handling of the databases involved should also be highlighted. In particular, the adequacy of the summarised trends in amounts of substance use and manufactured volumes is subject to the validity and reliability of the registered data within the databases. When it comes to our main source of such information – i.e. the SPIN database - this pertains to the accuracy of the amounts registered as annually used for each of the included substances. The limitations of SPIN are well described within the resource by the SPIN database developers and include, amongst others, imprecision in the values of total amounts used because of double counting for substances that are registered as raw material and preparations, and estimation bias arising from substance registration of concentrations in mixtures as intervals or means.[18] Estimation of the total substance volume is made by adding the quantities of the substance in all products, and having the export amount subtracted from this sum. Naturally, in some years exports may be lower than use and manufactured values for substances leading to storage of some of the annual production. This stored stock may be subsequently sold in one or more of the years that follow. Naturally these have implications on the estimated amounts and trends in use of the substances, with even negative values of several hundred or thousands of tonnes appearing in the figures of total amounts used.

Incompatibility of coding schemes for certain parameters is another important challenge faced that impinged on the pooling and analysis of the available databases. For example different coding schemes for industries and substances apply between different databases, with SPIN using the NACE v.2.2 and CAS registry system to code industries and substances, respectively; and the ECHA / CLP inventory and PRODCOM using its own ad-hoc coding system to code both industries and substances, respectively. On top of this, coding systems may vary also within databases due to periodic updates of the coding systems applied, such as in the case of the NACE coding system and development and revision from version 1.1 to the most recent version 2.2 in 2008. Although some mapping of the correspondence between the different coding systems or versions may be available,[19] implementation was quite laborious, with manual reviewing of codes and changes necessary, both pre- and post-implementation of the data standardisation process. It was not possible to implement such a full or automated standardisation process within the present work. Instead, encountering the very time-consuming extraction and manipulation of the original databases, we retrieved and collated data from the relevant databases only for periods for which the NACE v. 2.2. coding system was applied. Naturally this considerably reduced the time-period that could be studied within the project and impacted on the conclusions that were able to be made from the analysis performed. A longer study period (e.g. from 2000 to 2015) would have allowed more reliable conclusions to be made concerning the trends observed in used and manufactured volumes for the dangerous substances in question.

The applied substance selection and the analytical approaches and results of the project had to be reasonably constrained to be practicable. For example limitations had to be developed and applied via strict criteria of representativeness related to the substances use within countries. The country-specific selection criteria that we have applied restricted the dangerous substances to be included in the analysis to those having volumes of use >0 in all four Scandinavian countries, with application of the criteria preceded by another selection step where substances were omitted on the basis of their presence within the countries. Though occasionally altered to accommodate the needs of certain industries, these selection criteria, especially considering amounts used, are rather strict and are likely to have masked, either totally or partly, some relevant substances from our analysis. This is particularly relevant when considering substance use in a broader EU perspective than the

[18] http://spin2000.net

[19] http://ec.europa.eu/eurostat/web/nace-rev2/correspondence_tables

Scandinavian countries. Unfortunately, though similar data may be available and for other countries (see list of information sources in Appendix 5) these are not readily available for use.

6.2 SUGGESTED NEXT STEPS

Our analysis results suggest that it is feasible for the established methods to form the basis for, or be applied to, similar exercises in the future. Furthermore, they suggest that it may even be possible for the established methods to form an initial platform for the development of a more permanent, scientifically sound and data-driven surveillance system concerning the patterns of manufacturing, use and exposure volumes of dangerous substances within the European Union. The benefits of the establishment of such a system will be multi-dimensional, as such a system will allow the regular monitoring of trends in use, manufacture and exposure for known or suspected dangerous substances in EU industries. Once available this information can potentially be used to provide early warnings for exposure arising from increased use of known or emerging substances within certain industries, and to feed the establishment and performance of pro-active, targeted health and safety campaigns to prevent or control exposures to these substances in the workplace.

With improved integration and use of economic figures, some of which are already available within the current databases – e.g. annual value (in EU) of sold production within PRODCOM, use of the system could also enable the better planning of policies concerning substitution or restrictions in use for emerging dangerous substances including the future classification of substances as carcinogens. Last, but not least, once available, an integrated system like the one proposed above could be linked with the information systems and tools of projects like CAREX and SHECAN that aim to assess the burden of risk/disease and help to plan future assessments and to feed such systems with constant updates for their future estimations at both a national and whole EU level.

Some suggestions for improvements towards optimisation of the established methodology, both for the purpose of similar standalone exercises and towards the establishment of more sustainable and comprehensive surveillance system, may include (but are not limited to) those summarised below.

- 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. Focus on the Level 1 Data Summary Sheet characteristics could be first given with information from Level 2 integrated every time such an exercise is performed. Selection and review could be allowed on both a substance and an industry level.
- Further investigate and map database similarities and differences (gaps and overlaps); and exploit via data interchange which may be facilitated by improved import-export type facilities, and/or the use of data interchange web-based calls/APIs.
- Map in detail and standardise the data registered under different NACE systems across the included databases (i.e. SBS, JSFQ, LFS, SPIN, PRODCOM and other relevant databases to be included in future). This will

allow surveillance for longer periods regarding past patterns/trends in the use and manufacturing of substances within industries – a limitation acknowledged and described in detail within the previous section.

- Extract and collate to the SPIN, EU employment and PRODCOM databases the full list of registered substances within the ECHA inventory, with individual tables accounting for those details concerning CLP and industry classifications in the database. Current extractions of substance information from the lists have been performed at an industry level using CLP classifications as the restriction criteria. This approach is relevant for monitoring trends for known dangerous substances. Inclusion of the full lists will facilitate analysis on an ad-hoc basis, an approach particularly relevant for emerging substances – i.e. the history of use and exposure characteristics can be re-created for emerging substances which are currently used but are not identified as important and so dangerous within ECHA.
- By a more comprehensive analysis of the sources, map in detail the correspondence between PRODCOM codes and CAS numbers and update relevant database tables. This will allow surveillance of trends of manufacturing final articles, where certain substances are used. It will also allow the usefulness of the SPIN database as a representative source of trends in substance use at an EU level to be further evaluated while providing with better insight on trends in substance use within industries. For example chromium trioxide is used for chrome plating and SPIN data suggest a downward trend in use of the substance within the manufacturing of metal products industry (NACE code C25). If data are available, downward trends in use could be explored further by looking at potential correspondence between the SPIN data for the substance and the volumes/item numbers within PRODCOM for example for manufactured chrome-plated car pieces.
- Identify and integrate more databases holding national data regarding substance use and/or production volumes. This may include the previously highlighted as valuable (and comparable to the Nordic SPIN scheme) the substance register held by the Department Of Labour Inspections of the Republic of Cyprus[20] or more recent relevant initiatives such as the Belgian PROBE project.[21]
- Map potential connections and collate the data on the basis of different substance classification systems other than the CAS number register– i.e. by using the European Community-assigned substance numbers (EC numbers). From the present analysis findings it is evident that CAS numbers within ECHA and/or SPIN are frequently imprecise concerning the labelling and identification of the underlying substance definitions/names. Examples of such cases are the Silicon dioxide entries, which are cross-referenced between ISCO codes, and zinc metal which is registered also as Zinc oxide within the ECHA list of substances. The compatibility in use between the two coding systems and the reliability regarding their use within the currently available databases is worth being

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

[21] Godderis L, Pauwels S, et al 0264 Probe: hazardous chemical products register for occupational use in belgium Occup Environ Med 2017;74:A81-A82.

investigated with a view of moving towards the optimization of any established interface and analytical system.

Finally, the adaptation of a more flexible approach when defining criteria of representativeness for substance use across countries may benefit similar projects in the future. As previously described, a more flexible approach is likely to be more inclusive, concerning potential relevant substances in a broader EU setting than the Scandinavian countries. This is also likely to increase the numbers of combinations of substances and industries assessed for relevance by experts thereby facilitating the expansion of the pool of expert ratings initiated within the present work. Such a pool of ratings, which naturally would need to be updated at well-defined time intervals, will be beneficial for the establishment of the previously described surveillance system. The possibility of utilising or adapting components (e.g. exposure prevalences or indices) from other methodological aproaches within ongoing EU or international projects such as CAREX Canada (www.carexcanada.ca/) in this area should also be explored.

7 CONCLUSIONS

A great deal of analysis has been performed, resulting in an agreed strategy and the implementation of a feasibility study. The feasibility study has been successful in providing an initial strategy and platform for building a surveillance system for monitoring quantitative developments concerning manufacturing, use and exposure to dangerous substances in the future. With the initial application of the established methodological framework, which combines the analysis of actual data with expert assessment using well-defined criteria to evaluate the importance of the dangerous substances, suggestions considering the upcoming 2018-19 "Healthy Workplaces Campaign" are also provided. Sixty eight Level 1 Data Summary Sheets were produced, Those identified from the present work and implemented in Level 2 Data Summary Sheets include a) the exposure to crystalline silica of workers in the construction, mining and manufacturing industries, and b) the exposure to non-infectious bio-aerosols such as fungal and cell-wall microbial agents for workers on the waste management and recycling industries. In view of these findings, potential limitations of and suggested improvements to the elaborated methodology have also been identified and presented. These include, amongst others, the improved mapping and standardisation of the available data and coding systems applied, and the development of an integrated system and interfaces to retrieve, collate, update, and analyse the data in standardised and easy to read outputs.

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As usual, any errors and omissions are the responsibility of the authors.

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