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ABSTRACT

In France, laws require each company to draw up an inventory of the risks that may threaten employees' health in order to prioritize the preventive actions to be implemented. Focusing on chemical risk, databases on hazards or exposures are widely available but they lack information regarding chemical risks resulting from combining the hazards of chemicals with their conditions of use, thus generating exposures. Our objective is to build a matrix of French work situations associated with their chemical risk. Eighty-eight work situations were collected from reports written by professionals from the French public health insurance service. Each work situation is defined by descriptive parameters of the task, the exposure and the hazard. According to an expert elicitation method (Delphi, n=21 experts), each work situation was assessed and a chemical risk score defined, taking into account all the descriptive exposure and hazard parameters. Chemical risk scores were expressed as a range of values from 0-100, with the size of the range chosen by the experts themselves according to their uncertainty. The experts' assessments were merged to assign one risk score for each work situation, variability and confidence. The results showed that 50% of the work situations had a risk risk score between 40 and 60. The average variability and confidence were around 15% and 82%, respectively. This work situation matrix constructed from French data can be used by occupational safety and health managers that have similar work situations in their company (Western European industrial sector). In this context, it may be useful to easily determine the level of risks for similar tasks and prioritize those that are most risky. Moreover, it could be used to compare and define the differences between a risk assessment performed by "expertise" and another defined by a software.

INTRODUCTION

The aim of Occupational Safety and Health is to prevent and control all types of occupational risk: this implies prioritizing actions, often starting by reducing occupational hazardous factors at work (World Health Organization 2001). More specifically, in order to prioritize actions in occupational safety, it is necessary to carry out a health risk assessment. For chemical risk, the principle is based on the combination of two main parameters: hazard and exposure. It involves the identification and characterization of all types of hazards, as well as the description of the exposure conditions that might generateF a risk. Therefore, several types of tools have been developed to help characterize the hazard and assess exposure potential.

Regarding hazard identification and characterization, numerous databases have been developed to obtain data on the toxicity of chemicals. For example, the WHO/IPCS INCHEM Database described by Meek et al. (2011) is a tool that provides rapid access to internationally available information on chemicals published through the International Programme on Chemical Safety (www.inchem.org). Numerous types of chemicals from the full range of exposure situations (environment, food, occupational) are included. In addition, at the European level, the regulatory C&L Inventory database (https://echa.europa.eu/fr/information-on-chemicals/cl-inventory-database) contains classification and labelling information on registered and notified substances on the European market. At the company level, there are regulatory documents such as safety data sheets (SDS) which gather information related to occupational safety and health and also instructions for the safe use of substances, products and materials. For example, in France, the toxicological datasheet database from the INRS (http://www.inrs.fr/publications/bdd/fichetox.html) provides information concerning hazards and regulations and also medical and technical advice for more than 300 chemical substances.

Several occupational chemical exposure databases are available in the framework of exposure assessments. They contain workplace exposure measurements for various sectors of activity. Among the oldest is the MEGA database from the Institute for Occupational Safety (IFA) of the German Berufsgenossenschaften (BG). As mentioned in the study of Gabriel et al. (2010), this databank has included over 2 million workplace measurements of chemical and biological agents since 1972. The Integrated Management Information System (IMIS) serves the same function in the United States. Lavoué et al. (2013) stated that this database was created in 1979 and contains a very large set of workplace air measurement data collected and maintained by the Occupational Safety and Health Administration (OSHA) since 1976. In France, there are two occupational exposure databases, Colchic and Scola, that have been developed by the French National Research and Safety Institute for occupational risk prevention in France (www.inrs.fr). Colchic, created in 1986, centralizes more than one million exposure measurements collected by INRS and the inter-regional chemistry laboratories of the health and pension insurance service (Vincent et al. 2001). In addition, Scola, created in 2007, records more than 80,000 exposure measurements collected by accredited organizations operating according to French regulations. Both these databases provide an overview of occupational exposures to different chemicals for the sectors of activity considered as presenting the highest chemical risk in France, according to Mater et al. (2016). In addition, job exposure matrices (JEMs) can be used to estimate occupational exposures in occupational settings. These matrices contain lists of exposure data, exposed populations and probabilities regarding various chemicals in specific sectors of activity and occupations. As mentioned in the review by Sadhra et al. (2017), JEMs have been constructed and increasingly used all over the world over the past two decades. In the United Kingdom, Pannett et al. (1985) developed a JEM for use in population-based studies of

occupational morbidity and mortality. In the United States, Sieber et al. (1991) built a JEM based on exposure data collected from the 1972-1974 National Occupational Hazard Survey (NOHS). Furthermore, in Finland, Kauppinen et al., (1998) developed a new job-exposure matrix that contains more information than the standard JEMs: definitions, inferences, exposure data and references. This modified JEM can be applied as a general exposure information system for hazard control, monitoring and risk quantification. In France, Fevotte et al., (2015) described several job-exposure matrices adapted to the general French population (Matgéné program) that were constructed to estimate the prevalence of occupational exposures in the population and to study variations in this prevalence according to several parameters (e.g., gender, age, region, and so forth).

In France, as in other countries, occupational risk assessment is part of each employer's regulatory obligations (Safety and health at work EU-OSH - Directive 89/391/EEC). For each company, an inventory of the risks that could threaten an employee’s health has to be drawn up. Its aim is to prioritize the prevention actions that will be implemented. While both information about hazards and exposures and tools are widely available, as mentioned previously, there is a lack of information regarding chemical risk resulting from the combination of hazard and exposure. However, in each given work situation, this is the risk that employers must assess for the needs of prioritization. According to the sector, company and activity, each work situation is unique and specific and it is difficult to model chemical risk using only the existing hazard and exposure databases. Therefore, our objective is to build a matrix based on real work situations existing in different sectors of activity in French industry. In this matrix, each work situation is associated with a chemical risk score, taking into account hazard and exposure. This matrix could be useful for companies to determine the level of risk of their work situations if they have

any similar to those presented in the matrix, as it would allow them to easily define the preventive actions that must be implemented. Moreover, it could be used to compare and define the differences between a risk assessment performed by "experts" and another defined by a tool.

METHODS

Eighty-eight work situations representing different sectors of activity in French industry were collected from reports written by professional occupational hygienists from the "Caisse d'Assurance Retraite et de Santé Au Travail (CARSAT)," a French public health insurance service. Among other tasks, this service is in charge of occupational risk and disease prevention, and assisting enterprises regarding health and safety at work. The work situations are defined by the task description and the hazard and exposure parameters. Using the Delphi technique described by Dalkey et al.(1963), each work situation is assessed by a panel of 21 experts in order to define a chemical risk score of each of them.

Identification of typical work situations in France and the collection of relevant data

The INRS maintains a thesaurus of tasks associated with chemical risks performed in French industry. This thesaurus contains 70 large families of tasks that include approximately 400 precise tasks (e.g., manufacturing composite material parts, surface care and treatment, the steelmaking industry and the transformation of ferrous and non-ferrous metals, etc.).

Based on these families of tasks, a search was carried out on a specific documentary portal managed by the INRS to collect hazard and exposure parameters. This portal (INRS - Portal documentaire) gathers specific scientific and technical literature (18 000 books and 63 000 journal articles) and French and European legislation on occupational health and safety. The

search covered the period from 2000 to 2019 using the keywords: workplace risk, occupational exposure, chemical risk assessment and work situations; and keywords that represent the family of tasks concerned. Publications were selected in line with the following criteria: (i) French data, (ii) workplace chemical-related health risk, (iii) and considering the inhalation route only. More than 1000 documents were initially collected, including articles, brochures, the graduate thesis reports of public health insurance professionals, etc. Publications were then further selected with the following criteria: the abstract addressing the research subject and containing the task description, list of chemicals, and description of exposure. Finally, 63 detailed work situations from the graduate thesis reports of 56 public health insurance professionals were provided. Professionals from the French public health insurance service wrote these thesis reports after graduating, following several years of field experience in OSH.

The reports did not cover all the large families selected from the INRS thesaurus. Therefore, using available data on the internet describing industrial processes, information on the use of products available in the SDS, and by asking experts, twenty-five work situations belonging to the missing families were created and added to the list.

Finally, eighty-eight work situations were gathered. The work situations are described by the variables given in Table 1.

Risk assessment with the Delphi technique

The chemical risk assessment was carried out using the Delphi technique (Dalkey et al. 1963), a structred interactive prediction technique that involves a group of experts who respond anonymously to a question and then receive feedback as a synthesis of the "group's response", after which the process repeats itself. The objective is to reduce the range of responses and the

level of variability among participants. In total, 41 experts with different profiles including toxicologists, occupational physicians, chemical experts and experts in chemical risk prevention, were solicited to carry out a two-round assessment. Of these, 17 completed both rounds of the assessment (Table 2). We chose different profiles to represent the various topics needed in occupational chemical risk assessment and to have a risk assessment as complete as possible, by considering all the possible approaches, opinions and positions in terms of chemical risk prevention.

Nine information meetings were organized to explain the procedure to be followed by the experts. Access to data was ensured through a private secured cloud, and consisted of an Excel file with all the relevant information regarding the situation descriptions, the hazard and the exposure parameters, and 49 spare files for the safety data sheets of the products. The experts were asked not to share their experiences with each other. For each work situation, using a scale from 0 for very low level and 100 for very high level, they first established a hazard score and an exposure score according to the task description, the hazard and exposure determinants and their experience. Then, they were asked to assess each work situation by establishing a risk score that combined the exposure and hazard scores given previously. The risk scores were expressed as a range of values between 0 for minimal risk and 100 for the highest risk. The experts were asked to define by themselves the "high", "medium" and "low" levels while keeping the limits of the scale fixed. The size of the range was also chosen by the expert and represented the level of uncertainty that they considered in the light of the available data.

In addition, the experts were asked to justify their assessments with comments expressing their opinion on the hazard of the products used and the exposure parameters; i.e. whether the data provided were sufficient, whether important information was missing, and the uncertainty

they assigned to the situation to justify the risk score they chose. Each expert filled the fields in the Excel file and sent it back anonymously when finished.

For the second round of assessment, the experts who submitted their first round assessment were asked to repeat the chemical risk assessment for each work situation. The purpose of this re-assessment was to enable each expert to review their chemical risk score by considering the average score defined by all the panel members. This made it possible to obtain more refined risk scores with, if possible, smaller discrepancies.

For the second round, the document provided to each expert was an Excel file that included, in addition to the work situations, the results of the first round of expertise, i.e. the first round average risk score for each work situation, the average confidence level and the average variability for each work situation. A brief summary of the supporting comments from all the experts was also added to the document.

Aggregation of the risk scores

Once all the chemical risk assessment files for the second round were received, the risk scores of each work situation were compiled to define a final risk score. Probabilistic methods were used to merge the different assessments: Monte Carlo sampling (script developed in Java language,V.13, Oracle, Redwood Shores, CA) was used for computing a risk probability distribution that combined all the assessments for each situation. Each score (range of values) was represented as a uniform distribution over the range defined by the expert. The statistical indicators computed were:

- Indicators regarding the experts

- ***The expert's average score,*** defined by the average of the risk scores assigned by the expert. The higher this average, the higher the risk score assigned by the expert and thus the more conservative the expert was.
- ***The expert's uncertainty***, defined by the average range size of the scores (max – min) given by the expert to all the work situations: the expert with the lowest average range size had the most confidence in their assessment.
    - Indicators regarding situations
- ***The risk score*** of the situation, represented by the arithmetic mean of the final distribution of scores given by the experts. To simplify the description, the risk score could be considered as low, medium or high according to three levels 0-33, 34-66 and 67-100, respectively.
- ***The confidence*** of the experts: This indicator was determined by the difference between the maximum confidence value (100) and the average size of the ranges (max – min) given by all the experts to the situation, which represented the level of doubt of the experts regarding the score defined. For example, for a work situation with an arithmetic mean range size of 20, the confidence level was 80%.
- ***The variability*** of the risk assessments**,** represented by the standard deviation of the scores given by the experts. The smaller the standard deviation, the less variability in the risk assessment, thus the better the agreement between experts.

The reliability of the expert assessments was assessed by sampling the risk scores so as to simulate the results that would have been obtained with a smaller number of experts. More specifically, each possible combination of k expert assessments out of n total expert assessments were prepared (k<n ; no replacement ; C_n^k samples). The corresponding sampled risk scores were

calculated. The percentage difference between the arithmetic average of the sampled risk scores and the actual risk score for all the experts was calculated and discussed.

The experts' comments were examined one by one in order to synthesize as closely as possible the experts' opinions and to have a clear and precise idea of the justifications for the risk levels defined and the reasons for the uncertainties. When the comments of the experts were different, which was often due to uncertainties related to the exposure part (lack of detail regarding certain descriptive parameters), the uncertainty and its reasons were also noted in the synthesis. These supporting comments were particularly useful to justify situations where risk levels were different (high variability between experts) and to note the possible limitations associated with the input data.

RESULTS

Identification of typical work situations in France and the collection of relevant data

The data on 88 French work situations were collected and analyzed. Various types of companies were represented by these work situations. The sectors of activity most represented were: building and construction (16 %), automotive (11 %), metallurgy (11 %), and printing (7 %). Table 3 shows two examples of work situations with their exposure and hazard determinants: "electrostatic powder coating" and "welding". All the work situations are described in the chemical risk matrix available in Supplemental File 2.

Two hazard typologies were identified in these work situations: chemicals from labeled products, which concerned 59% of work situations like painting, gluing, and so on, and those

emitted during the process, which concerned 41% of work situations like plastic extrusion and welding, etc.

Risk assessment with the Delphi technique

The risk assessment phase lasted 5 months. For the first round, 25/41 experts participated in the risk assessment. They included 16 experts from the INRS (two toxicologists, one occupational physician and 13 chemists and OSH professionals), eight OSH field experts from the French health insurance service and one university toxicologist. In the second round, the same experts were solicited. 17/25 experts participated, i.e. 41% of all the experts solicited originally: they included 10 experts from the INRS (one toxicologist, one occupational physician and eight chemists and professionals in OSH), six OSH experts from the French health insurance service and one university toxicologist.

Aggregation of risk scores

The results (Figure 1) show that 50% (43 out of 88 situations) of the work situations had an aggregate risk score between 40 and 60. Twenty-seven percent of the situations had an aggregate risk score below 40 (24 out of 88), and 24% had a risk score above 60 (21 out of 88). For example, the aggregate risk scores of the tasks “Electrostatic powder coating” and "welding" previously mentioned were 32 and 69, respectively. The risk score of the situation "Electrostatic powder coating" was low: the exposure was described by a dispersive process, an amount of 160 grams per day, and the use of collective protective equipment (ventilated booth). The level of exposure was considered “low” by the experts, according to their supporting comments. In addition, for hazard identification, the product was classified as “causing serious eye irritation”, “causing skin irritation” and “may cause an allergic skin reaction” according to the CLP

regulation. The level of hazard was considered “low” by the experts. The risk score of the situation “welding” was high: the exposure was described by a dispersive process performed with general ventilation without any other collective or individual protective equipment; the level of exposure was considered “high” by the experts, according to their supporting comments. In addition, for hazard identification, the welding fumes emitted during this process are potentially harmful and can be the cause of intoxication leading to the occurrence of acute or chronic pathologies. The hazard level was considered “high” by the experts.

The variability, shown in Figure 1a, varies between 8% and 28% over all situations. The average variability is 15%. Sixty percent (52 out of 88) of the work situations have a variability lower than 15% and 40% (36 out of 88) of them have a level of variability higher than 15%. The two examples of tasks, “Electrostatic powder coating “and "welding", have a variability of 24% and 17%, respectively. The work situation with the highest variability (28%) is the situation of "loading demolition debris", performed outdoors and without any individual protective equipment. The risk is related to exposure to mineral and crystalline silica dust. The risk score for this situation was medium (65). The experts considered a high hazard level in the justifying comments. The high level of variability may have been due to the difference in the experts’ interpretation of the exposure parameters. For example, outdoor work may have been considered as sufficiently naturally ventilated by some experts, while others may have considered the proximity of debris loading to the airways of the workers. In contrast, the work situation with the lowest variability (8%) was “cleaning small metal parts” in a heavy truck dealership; performed indoors via an open process without any collective or individual protective equipment. The risk score for this situation was medium (63); it is related to exposure to a decalcifying cleaner that “causes skin irritation”, “causes serious eye irritation” and “may cause drowsiness or dizziness”

according to the CLP regulation; the hazard level was "medium" according to the experts. The low level of variability was related to the fact that the experts rated very close risk levels for this situation.

The reliability of the risk scores was assessed by calculating the average risk scores obtained for the 136 possible combinations of 15 experts out of the 17 who participated in the second round ($C_{17}^{15} = 136$). For each situation i, the arithmetic average of the 136 sampled risk scores was calculated and compared to the actual aggregate risk score. Overall, the percentage difference varied from -0.24% to +0.48%, showing remarkable reliability in these conditions.

Confidence, shown in Figure 1b, varies between 62% and 87%. The average confidence is 82%. Sixty-seven percent (59 out of 88) of the work situations have a confidence level higher than 82%, while 33% (29 out of 88) of them have a confidence level lower than 82%. The two examples of tasks “Electrostatic powder coating “and "welding" have a confidence of 84% and 85%, respectively. The work situation with the lowest confidence (62%) is a situation of "supervision of fireworks firing" performed outdoors without any individual protective equipment. The risk score related to this situation is medium (49). The low confidence expresses the difference in the knowledge levels of the experts concerning the sector of fireworks as well as the lack of detailed data on this type of hazard. It was described in the justifying comments, in which the experts mentioned that they had no knowledge of this type of situation. Conversely, the work situation with the highest confidence level (87%) was that of “discharging a solvent” in a company processing pre-printed paper supports, performed outdoors in a closed process and without any individual protective equipment. The risk score of this situation was low (32); the hazard associated with the effects of the solvent "causes serious eye irritation" and "may cause drowsiness or dizziness" according to the CLP regulation was considered medium by the experts.

The exposure was low according to the experts because the task was performed outdoors in a closed process. The high level of confidence was related to the fact that the situation was well described, and the data provided were sufficient to define a level of risk.

The experts' average scores and their uncertainty

The experts' average score was defined by the average of the risk scores defined by the expert for all the work situations. This score reflected the level of conservativeness of each expert. The expert's level of uncertainty was defined by the average size of the ranges given by the expert to all the work situations. These two indicators calculated for each expert are shown in Figure 2.

The experts' average scores varied between 40 and 72. The mean of these scores was around 52. Fifty three percent (9 out of 17) of the experts had an average score below 52, while 47% (8 out of 17) of them had an average score above 52.

The experts' uncertainty levels varied between 0 and 45%, with an average of 21%. Among the 17 experts, 53% (9 out of 17) had uncertainty levels below 21% while 47% of them (8 out of 21) had uncertainty levels above 21%. Expert "E" reported scores without using ranges, so their level of uncertainty was zero. Experts "P" and "M" were rather less certain in their assessments, with uncertainty levels above 30.

DISCUSSION

A list of real work situations representing various sectors of activity in French industry was drawn up. Each work situation was associated with a score representing the level of risk. The scores were aggregated from assessments given by a panel of experts with different profiles and skills. To our knowledge, this is the first time that a matrix of real work situations associated with a level of risk based on a combination of hazard and exposure has been proposed.

Parameters used for hazard and exposure characterization

As no similar risk matrix is available, a direct comparison with other matrices is not feasible. Nevertheless, it is possible to compare the parameters included in our risk matrix with those used in different risk management tools from universities, such as the health and safety chemical risk form of the University of Melbourne, Australia(available from: https://safety.unimelb.edu.au/ __ data/assets/work_ doc/ 0010/1714915/Chemical-risk-assessment-form.docx;), the chemical risk assessment worksheet of the University of Curtin, Australia (available from: https://healthandsafety.curtin.edu.au/Example_GreenChemicalRiskssessment.pdf), and the risk assessment tool of the University of Memphis, USA (available from: https://www.memphis.edu/ehs/xls/risk_assess_tool.xls). Briefly, these tools rely on the completion of a questionnaire based on data from the SDS of the products and their conditions of use, e.g., process, amount, frequency and duration. These parameters are similar to those used in our risk matrix, except for frequency and duration of exposure. These parameters were not used because the aim was to evaluate the risk related to the task and not to the work station. In general, the purpose of our risk matrix differs from that of risk management tools. Indeed, the user of these risk management tools evaluates a situation by answering a questionnaire and makes a decision on the risk via the decision grid provided by the tool. In contrast, in our matrix, the objective was to define reference risk scores and obtain an idea of the diversity of expert interpretations.

Expert elicitation method used in chemical risk assessment

The Delphi technique was chosen from among all the methods of eliciting expert opinions (European Food Safety Authority., 2014). This technique is commonly used in the literature on

health services like the study of McMillan et al.(2016), in risk assessments of human health such as the studies of Rowe et al. (2016), Huang et al.(2008), Vance et al.(2015) and Adam-Poupart et al.(2013), and animal health such as the study of Bertocchi et al.(2018), but is rarely used for occupational chemical risk assessments. It was chosen because it allows the inclusion of a large number of participants without the need for physical meetings or exchanges between them, unlike the other methods such as the Sheffield method which usually involves between 6 to 10 experts at most, as described in the CES REACH-CLP (2021) report and a single collective face-to-face meeting. In addition, according to Rowe et al.(2001), the anonymous nature of the Delphi technique allows the group members to express their opinions in private, without the effects of influences or pressures exerted by dominant or dogmatic individuals, or by a majority. This allowed each expert to evaluate the work situations in the light of their own skills and experiences. The Delphi technique is interesting for our study because it allowed integrating the reality of the field by involving human experience instead of using only the aggregation of "quantified" parameters: "hazard" data of the CLP, exposure data like quantity and duration. In our study, like others related to human health risk assessment (Rowe et al. (2016), Huang et al. (2008) and Adam-Poupart et al. (2013)), the basic steps of Delphi described in the study of Yousuf (2007) were followed, starting with the selection of experts to analyze the input and share the results with the panel. The selection of experts is an important first step because it is essential to consider their knowledge of the topic and their availability during the Delphi survey process. In the current project, the experts were carefuly selected based on their affiliation and their areas of expertise (chemists, occupational physicians, occupational hygienists, and toxicologists), their field experience (ten years or more) and their diversity ensures the quality of the assessment. Indeed, in their study, Benke et al. (1997) quantified the potential effect of

exposure misclassification from using expert panels and showed that it could be a significant source of bias if the adequacy of the experts in terms of performances is not verified beforehand. This conclusion can be extrapolated to the risk assessment as well, so the adequacy of the experts' profiles and competencies for this project was considered. Other studies conducted by Logan et al. (2011), and Walker et al. (2003) showed that adequate training, skills and work experience can have a positive impact on the performance of experts. Moreover, a study conducted by Kromhout et al. (1987) showed that occupational hygienists were successful estimators of exposure; this could confirm the pertinence of our choice to have also engaged hygienists to carry out the assessment.

Generally, the goal of using the Delphi technique is to achieve consensus among experts, as noted by Bourrée et al. (2008) in their study. In this study, the goal was not to seek consensus but rather to have more robust and reliable risk scores. This is the reason why only two-rounds were conducted: the first one aiming at defining the first risk assessment of the different situations and the second one aiming at reviewing the risk scores defined. This was also the choice of Vance et al. (2015), where the goal was to answer a question in the first round and then to rank the themes resulting from the first round according to their importance. In contrast, three rounds were carried out in the studies of Rowe et al. (2016) and Huang et al (2008), because their goal was to achieve consensus regarding the question. Thus, the risk assessment results obtained are assumed to be reliable for two reasons. First, the variability is low for most work situations. This shows good agreement between all the experts and thus confirms the reliability of the assessment as mentioned in the studies of Golberg et al. (1986) and Cock et al. (1996) who investigated inter-rater agreement in exposure assessment. Second, the results of the analysis that was performed by sampling the risk scores so as to simulate the results that would have been obtained with a

reduced number of experts showed a very small difference since the percentage on the score was lower than 1%. This fact contributes to the assumption that the agreement between the experts was good enough to confirm the good reliability of the assessment. This method differs from those employed by Stewart et al. (2000), Walker et al. (2003) and Logan et al. (2009). These authors were able to compare the results of the expert panel exposure evaluations with real exposure measurements. In this study, this was not possible because the risk assessment included subjective assessments.

Limitations of the study

One of the limitations of this work may be the absence of representativeness of the French occupational sectors and the small number of situations assessed (n=88). However, our goal was not to obtain representativeness of sectors, but rather a greater diversity of the sectors of activity most exposed to chemical risks. According to our literature search, i.e. the thesis reports of public health insurance professionals, we consider that this diversity was well represented here for the sectors targeted. However, the reports produced by public health insurance professionals chosen in this study did not cover the agriculture and medical sectors, which are also known to be sectors with significant chemical risks according to the Eurofound (2013) report.

The quality of the data describing the work situations was sometimes judged insufficient. Indeed, according to the experts' justifying comments, a lack of detail regarding certain descriptive parameters of the work situations was mentioned, especially those describing the exposure part. These parameters are "the type of process" and "the type of protective equipment", which were not sufficiently described in the experts' opinions. Furthermore, a lack of other descriptive parameters was mentioned in the comments, such as "the distance of the

employee from the source of emission", "the volume and surface of the work area", and "the amount of product". These parameters were not available for all the work situations. This lack of details and parameters can be considered as a bias in the exposure assessment and thus the risk assessment. It explained to a large extent the high levels of variability found for some work situations. In their studies, Teschke et al. (1989), Cock et al. (1996), Walker et al. (2001, 2003) and Logan et al. (2009) showed that professionals' judgments for exposure estimates may not be consistently highly accurate unless more data and training are provided. In addition, according to the experts' supporting comments, it would have been easier for them to have hazard and exposure levels instead of relying only on descriptive parameters to better assess the chemical risk. Furthermore, the reports of the public health insurance professionals did not contain all the data needed to construct the matrix. These missing data concerned the physicochemical properties of the products and the hazards. These data were found in the SDS of the products which were sought from other sources. In addition, for some work situations where chemicals have been banned from use, it was necessary to review and update them with more recent SDS.

The use of SDS to assess the hazards of products can be considered as a bias of the study. Indeed, a review conducted by Nicol et al. (2008) showed that accuracy and completeness were poor in SDSs and noted the high uncertainties regarding the role of SDSs as hazard communication tools. These findings concerned SDSs dating before 2011. Since 2011, the quality of SDSs has improved considerably following ECHA guidance on the drafting of SDSs in conformity with the obligations of REACH regulation no. 453/2010. However, SDSs are still not perfect nowadays and need more improvement according to the ECHA (2019) report.

CONCLUSION

This work allowed the construction of the first matrix of real work situations representing different activity sectors in French industry. The risk score for each work situation was defined by expert assessment using the Delphi technique. According to the results of the risk assessment per situation, a global consensus between the experts for both rounds was achieved. Indeed, the results of the two indicators, "level of variability" and "level of confidence", were acceptable for the majority of the work situations. This matrix can be very useful because it is the first matrix linking real work situations in French industry with their chemical levels of risk by the inhalation route. It can be used by occupational safety and health managers that have similar work situations in their company (Western European industrial sector). In this context, it may be useful to easily determine the level of risks for similar tasks and prioritize those that are most risky. Also, this matrix can be used to compare and define the differences between a risk assessment performed by "expertise" and another defined by a tool.

Our risk matrix will be used to the "expert" risk scores of each work situation with those calculated by the Seirich software (V 3.2, Seirich, France), which is a tool that helps companies to assess their chemical risks. The differences in risk assessments for each work situation will be studied in detail to determine their origin. This will allow us to identify and propose improvements for the software algorithms.

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Data Availability

The matrix is provided in online supporting material so other researchers can use it.

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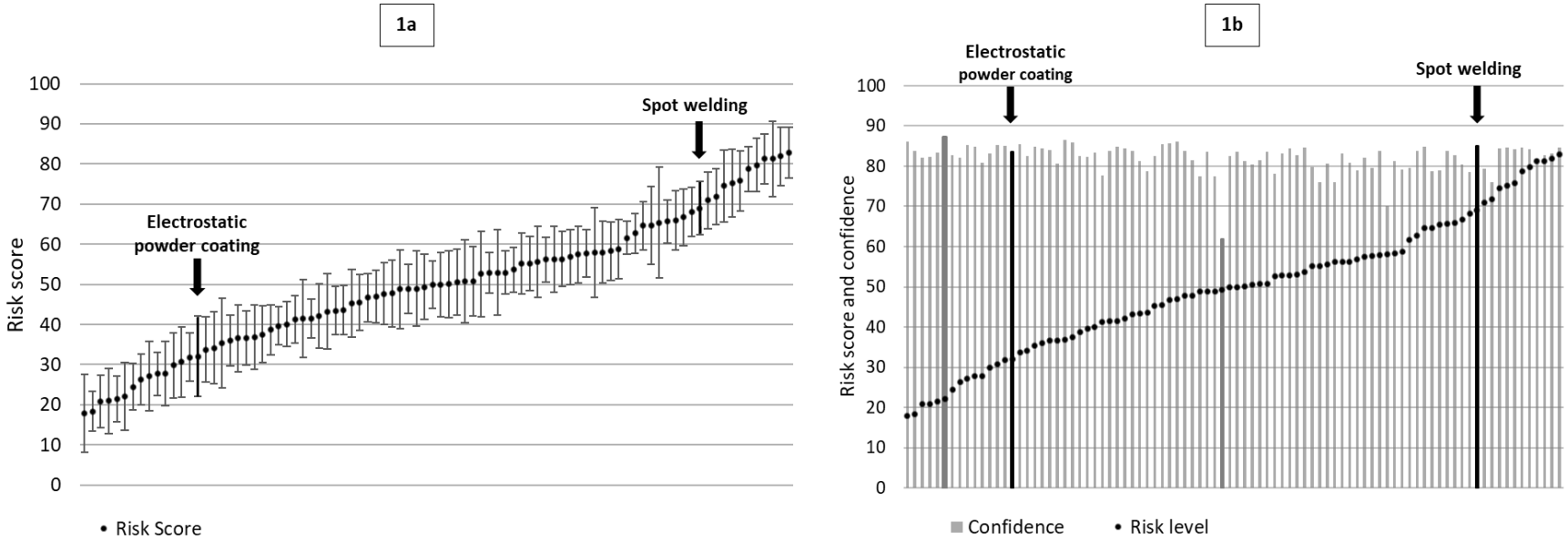

Figure 1. Aggregate risk scores for the 88 French work situations identified with the Delphi method. The work situations are ranked in ascending order of their risk scores, from the situation with the lowest risk score to the one with the highest risk score. The risk scores, represented in black circles, are associated with the variability expressed as an error bar in 1a; and with the confidence level (%) for each situation (grey bar chart) in 1b. The work situation with the lowest confidence level and the one with the highest confidence level are represented in dark grey. The two examples of tasks “Electrostatic powder coating” and "spot welding" are represented in black and bold.

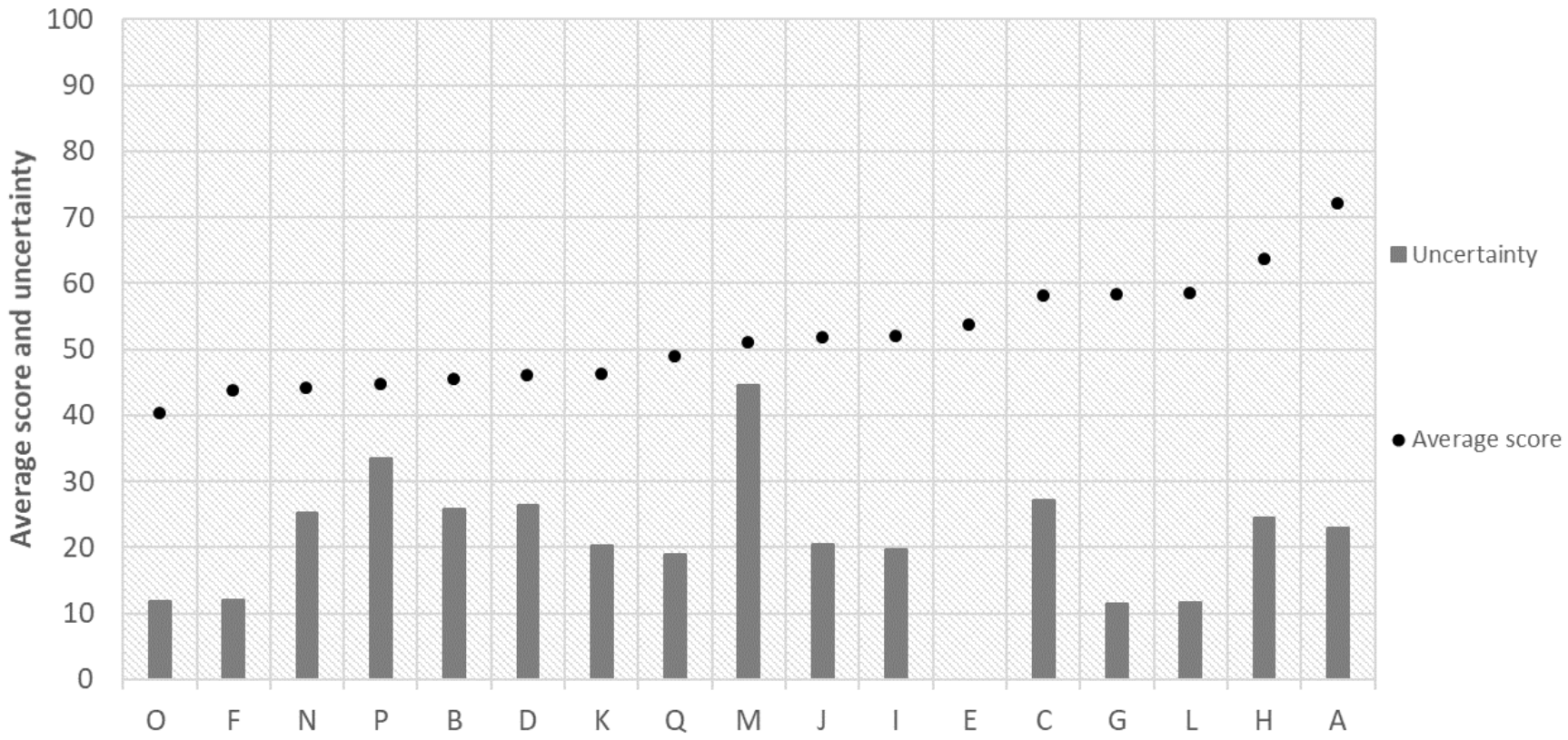

Figure 2. The average score and uncertainty level for each expert who is identified by a letter to respect the anonymous nature of the study. The average scores are ranked in ascending order and are represented as black circles. The uncertainty levels are represented with the grey bar chart.

Table 1. Data used to describe the work situations, in terms of exposure and hazard parameters

Description of the task	**Exposure parameters**				**Hazard parameters** Based on the task performed, the hazard can be either a product (e.g., a solvent) or chemicals emitted from the process (e.g. welding fumes). The parameters collected are not the same.	
	Type of process used	***Collective protective equipment*** [a]	***Daily amount of products***	***Personal protective equipment*** [b]	***Product***	***Chemicals emitted during the process*** [c]
Data describing the task performed (e.g., printing), the company (e.g., printing company), and the sector of activity. These data help the experts to	The types of processes are defined from the European technical guidance document on risk assessment* : -**Dispersive**: Any process which by the energy deployed or	Whether the task is performed outdoors or not. In case the task is performed indoors, the presence of a ventilation or collection system helps reduce the level of exposure to chemicals. The different modalities	It is given when it is mentioned in the original report; it corresponds to the quantity of the product used on one day.	The use of a personal protective equipment helps to refine the level of risk especially when the use of collective equipment is insufficient to allow a sufficient	Product name and its Safety data sheets: for chemical properties and hazard statements H and EUH (according to the CLP regulation)	Names of chemical emitted during the processes;

better understand the task described	the absence of containment generates emissions into the working atmosphere. **- Open**: Any process where the material is localized without specific dispersion but which does not have specific containment **- Enclosed but regularly opened:** Any process which is confined but which can be opened during filling, emptying or control phases **- Enclosed**: any process that is completely contained.	are · Operative / not operative general ventilation, · The use or not of a collection with the type (e.g. fume cupboard, booth) if existing		protection.		

a. This term refers to the ventilation controls and local exhaust ventilation
b. The use of personal protective equipment is indicated in the matrix to enable the experts to refine the level of risk they define.
c. The level of hazard of the chemical substances emitted during the process is evaluated based on professional skills and experience.

* Technical guidance document on risk assessment. [Cited 2021 Apr 28]. Available from: https://echa.europa.eu/documents/10162/16960216/tgdpart2_2ed_en.pdf

Table 2. Experts' profiles and affiliation

		First round		Second round	
Expert profil	**Affiliation**	**Experts solicited**	**Experts who participated**	**Experts solicited**	**Experts who participated**
Expert chemist and professional in OSH	INRS and University	15	13	13	8
Toxicologist	INRS and University	3	3	3	2
Occupational physician	INRS	1	1	1	1
OSH expert	French health insurance	22	8	8	6
Total		41	25	25	17

Table 3. Two examples of work situations with their exposure and hazard determinants.

Description of the task	**Exposure parameters (determinants of exposure)**				**Hazard parameters**	
	Type of process used	***Collective protective equipment*** [a]	***Daily amount of products***	***Personal protective equipment b***	***Product***	***Chemicals emitted during the process*** [c]
Electrostatic powder coating of a metal part in a railway seat manufacturing company	Dispersive	ventilated booth	0.16 kg/day	*operative*	Powder coating Classified as “causing serious eye irritation”, “causing skin irritation” and “may cause an allergic skin reaction” according the CLP regulation.	-
Welding of a metal piece in a heavy vehicles dealership.	Dispersive	General ventilation	-	*not operative*	-	*Welding fumes*

a. This term refers to the ventilation controls and local exhaust ventilation
b. The use of personal protective equipment is indicated in the matrix to enable the experts to refine the level of risk they define.
c. The level of hazard of the chemical substances emitted during the process is evaluated based on professional skills and experience.