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The perspective of European researchers of national OSH institutes for contributing to a European research Agenda: a modified Delphi study

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ABSTRACT

Objectives

This study, developed within the frame of the Partnership for European Research on Occupational Safety and Health (PEROSH) joint research activities, is the first example of using the point of view of European OSH researchers to identify priorities for OSH research that may contribute to the achievement of present and future sustainable growth objectives set by the European strategies.

Methods

The study was carried out using a modified Delphi method with two rounds of interviews. Each round involved a panel of about 110 researchers representing each of the network member institutes was selected according to specific criteria, including the ownership of research expertise in at least one of the four macro-areas identified by the reference report developed by EU-OSHA in 2013.

Results

The study identified some innovative Research Topics (for example "*Emerging technological devices*" and "*OSH consequences of markets integration")* and Research Priorities (for example *crowdsourcing, e-work, zero-hours contracts*) that are not reflected in previous studies of this nature.

The absence of any reference to violence and harassment at work among the researchers' proposals is a major difference from previous similar studies, while topics related to gender issues and electromagnetic fields show a lower importance.

Conclusions

The innovative design of a research priorities identification process, which takes advantage of a large, representative and qualified panel of European researchers allowed the definition

of a number of research priorities able to support the inclusion of innovative OSH research issues in the scope of the next European Research Agenda.

Keywords: Delphi study, research priorities, OSH, PEROSH, European Agenda

ARTICLE SUMMARY

Strengths and limitations of this study

- This is the first OSH Research priorities setting study able to provide a reliable expression of the perspective of the European OSH Research Community and an analysis of differences between European geographical areas thanks to the involvement of a wide, transdisciplinary and transnational panel of European highly qualified OSH Researchers from 12 preeminent European National Institutes.
- The study takes advantage of an innovative methodological path that integrates the top- down and bottom-up approaches in order to steer the Researchers' involvement in each step of the priority setting process towards the provision of feasible research priorities responding to 4 predetermined OSH research challenges identified by EU-OSHA on the basis of the development objectives set by European Strategies.
- A limitation of the study was represented by the possibility of researchers to promote their own research activities as priorities, which is inconsistent with the need of going beyond the boundaries of sectoral research and being highly interdisciplinary.
- Another limitation of the study was the composition of the researchers' panel, reflecting only the OSH competences related to the macro-themes shaped by the 4 challenges, devoid of the skills specific of correlated research fields that could be relevant for a broader assessment of the strategic and synergic impact of the priorities on the European research framework.

INTRODUCTION

Demographic changes, globalization and technological innovation, are continuously reshaping the world of work, with a direct impact on workers' health and safety (H&S).[1, 2] New occupational risk factors are emerging owing to the "introduction of new technologies, substances and work processes, changes in the structure of the workforce and the labour market, and new forms of employment and work organization".[3] Furthermore, changes in social or public perceptions and the development of scientific knowledge allow long-standing issues to be considered or identified as emerging risks.[4] Despite the good results already achieved by the European occupational health and safety (OSH) system in many fields (such as work injuries prevention), these changes require further efforts to allow the OSH system able to support a suitable level of workers' H&S protection.[5] OSH research, thus, needs to maintain a pivotal role in the development of policies for the improvement of workers' H&S, allowing the OSH system to timely identify and tackle emerging issues.[6]

Therefore, it is of the utmost importance to bring forward a strategic OSH research plan to ensure a timely, efficient and effective use of available resources to address the challenges presented by the changing world of work.

With this aim, in 2013 the European Agency for Safety and Health at Work (EU-OSHA) developed a study to connect OSH research objectives with both the Europe 2020 strategy and the Horizon 2020 programme and their key objectives of 'smart, sustainable and inclusive growth' and 'excellent science — competitive industries — better society'.[7-9]

The study identified four major challenges, which OSH research should use to support the pursuit of these objectives, as well as the research priorities to tackle these challenges.

This study is the most recent in a series of national and European level studies started in the early 1990s to identify research priorities able to fill the OSH knowledge gaps caused by the

changes in the world of work.[10]

An accurate review of such studies, though, showed that at European level a methodical and structured elicitation of the researchers' view aimed at the identification of research gaps and a fine-tuning of well-defined research priorities has always been missing. In the majority of cases, researchers' involvement in the development of these studies was marginal and in any case downstream of previous elaborations developed by selected teams of OSH experts. Also, the findings of the 2013 EU-OSHA study, despite consultation with a larger panel of OSH experts (including researchers, in addition stakeholders and other OSH professionals), were strongly rooted on a preliminary and in-depth desk analysis carried out by a restricted team of experts.

The only European level study which saw a large and effective involvement of researchers (alongside other OSH experts) was based on a set of four Delphi surveys conducted by the EU-OSHA Risk Observatory between 2004 and 2006.[4, 11-13] Nevertheless, this study focused more on new and emerging risk factors than on real priorities for research, and its final output was the identification of general OSH issues to be addressed.[14]

On the other hand, there are a number of well-documented national studies aimed at supporting the drafting of OSH research strategies which, beside the participation of different experts (OSH professionals, OSH services, policy makers, social parties, etc.), provide a full and direct involvement of the researchers' community in the priorities setting process. Such experiences, mostly based on Delphi surveying methods, took place in the USA, Malaysia, UK, Netherlands and Italy. Some of these studies (Italy and Netherlands) also provided a distinct representation of researchers' point of view.[15-20]

The importance of surveying the research community is based on the premise that researchers, as main actors of research activities, are in a very strong position to provide a

real time and realistic picture of the state of the art and to define what is currently missing to properly tackle the upcoming challenges. Furthermore, a wide, substantive and full involvement of researchers in the process of identification of research priorities can assess their feasibility, according to the current scientific evidence, and their consistent integration into existing research activities. Therefore, a clear and accurate representation of the research community's expectation provides a useful starting point for a strategy planning process aiming to produce an OSH research agenda. [21, 22]

For this reason, in 2014 the Partnership for European Research on Occupational Safety and Health (PEROSH, a network of 12 OSH research institutes across Europe) approved the joint research project "Futures. Foresight and priority setting in OSH", led by the Italian National Institute for the Insurance against Work Accidents (INAIL) with the collaboration of the Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA, Germany), the National Institute for Research and Safety (INRS, France) and the Health and Safety Laboratory (HSL, UK).

Starting from the challenges identified in the 2013 EU-OSHA study, [7] the "Futures" project aimed at providing an updated identification of research needs and at prioritizing them by the level of consensus among the researchers working in the network member institutes. To this end, it took advantage of the critical mass of researchers working in the member institutes and of the good geographical coverage of the network itself. Unlike previous European level studies focusing on foresight activities and using the Delphi method, this is the first one to include only researchers in the Delphi panel and to focus exclusively on the identification of research topics and priorities, which the OSH research community considers fundamental for an effective development and improvement of the OSH system.

This study modifies the top-down approach to the elaboration of the Research Agenda, with

a bottom-up process where researchers represent the primary source for the identification of future research priorities, and not only the final step for the assessment of proposals developed by a small number of experts.

The purpose of this study is to provide a timely contribution to the development of the next 2020-2030 European OSH research agenda in order to allow its effective alignment with the needs arising from the world of OSH research. It offers a clear picture of the researchers' point of view, which may represent the baseline of a strategic planning process, which should subsequently include a wider community of stakeholders. The study also needs to react to the increasing reductions in funds for OSH research, as priority-setting processes are critical in aligning research funding with evidence needs as well as in supporting an efficient allocation of limited resources available for research.

METHODS

The study was based on a two-round modified Delphi survey, which involved a panel of researchers from all PEROSH institutes. The project's leader and co-coordinators (Coordination Group) developed the methodological path and shared it with the PEROSH Steering Committee. The method used is illustrated in Figure 1.

Step 1 – Desk analysis

The first step consisted of an in-depth analysis of the EU-OSHA report "Priorities for occupational safety and health research in Europe: 2013-2020", aimed at updating OSH research priorities identified in 2005 and taking into account the latest developments in scientific knowledge, the changes in the world of work and the impact of recent trends on OSH. The report also considered the priorities and key objectives set in the Europe 2020 strategy and the Horizon 2020 programme.[7, 23, 8, 9]

The EU-OSHA report includes four macro-areas, which were taken as landmarks for the

present study:

1. **Demographic change** – sustainable work for healthier and longer working lives.
2. **Globalization** and the changing world of work – OSH research contribution to sustainable and inclusive growth.
3. OSH research for **safe new technologies** as a prerequisite for sustainable growth.
4. Research into new or increasing occupational exposures to **chemical and biological agents** for the benefit of a smart and sustainable economy.

All the PEROSH institutes contributed to the study by providing contact persons. Their task was to identify 5 to 20 expert researchers to be included in the panel, provided they had a specific research experience (at national and possibly also international levels) in one or more of the four macro-areas and a present or planned direct involvement in research activities related to the relevant macro-area.

Step 2. Delphi questionnaire – First round

The first round took place between March and April 2015. For each macro-area, a specific open-ended electronic questionnaire was sent to a subpanel of researchers, selected by their area of expertise. Some researchers were indicated as experts for more than one macro-area.

Participants were asked to list, within their macro-area of interest, three to five well-focused research issues on which there is a need for further research.

Step 3. Delphi questionnaire – Second round

Starting from the research proposals returned at the end of the first round and using keywords and recurrences of concepts to group together similar issues and to reduce the total number of research proposals, the Coordination Group elaborated a structured questionnaire divided into 16 “Research Topics” (RT), each one containing a list of consistent

"Research Priorities" (RP).

The identification of the RT was based on the main structure of the EU-OSHA report, reflecting the general content of each macro-area.

Before the second round, a preliminary pilot test was performed to assess accessibility of the platform and comprehensibility of the research proposals as well as to estimate the duration of the interviews. The pilot study involved 16 participants identified within the Coordination Group institutes. Feedback and comments were taken into account in designing for the final version of the survey.

For the second round of consultation, which took place between February and March 2016, the questionnaire was sent to the entire sample of researchers involved in the project, irrespective of their area of expertise and of their active participation in the first round.

In this round, researchers were asked to rate the level of importance of each RP and RT considering whether it is addressing a real OSH research gap and the impact that OSH research might have in terms of the breadth of the workers' population affected and the severity of avoidable damages to health. The rating system was based on a scale of importance, from 0 (=not at all important) to 5 (=extremely important). The system provided also the "I don't know" option, allowing those researchers who felt not to have enough expertise on a specific item to abstain.

The questionnaire was circulated in English through the dedicated web-based platform SurveyMonkey®; the researchers involved received an electronic invitation by email, directly generated by the system. Two reminder emails were sent, the second one informing of a one-week extension of the deadline to increase the response rate.

To reduce response biases, the system provided a randomization of the RP in each page and a reversed order of the pages for 50% of the sample. The page with the list of RT was

excluded from any randomization process.

Ratings given in the second round were analysed by calculating Mean Values (MV) and Standard Deviation (SD) for each RP and each RT. SD values were considered as a "consensus indicator".

Percentages were also calculated considering those attributing no importance at all (0) and grouping together those attributing a low level of importance (little - 1 - or slight importance - 2), and those attributing a medium-high level of importance (from moderate - 3 - to extreme - 5) to each RP and RT.

A geographical classification of participants, based on a modified UN classification, was performed, grouping together Denmark, Finland, Norway and UK for Northern Europe; Austria, France, Germany, the Netherlands and Poland for Central Europe (Western and Eastern Europe were gathered together as Central Europe to assure a homogeneous representativeness of researchers in the sub-samples); and Italy and Spain for Southern Europe. MV for each RP and RT were calculated with respect to the geographical distribution; statistically significant differences were evaluated by applying the Kruskal Wallis test; Post Hoc tests were used to assess which MV were significantly different from the others. The Post Hoc tests used were Bonferroni or Tamhane, depending on whether variances were homogeneous or non-homogeneous according to the Levene test. Significance was set at $p<0.05$. Data were analysed using SPSS Statistics V. 21 (SPSS. IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp, 2013).

RESULTS

In the first round of Delphi, 126 questionnaires were forwarded to 110 researchers; some researchers received more than one questionnaire as they were quoted as experts in more than one macro-area. 94 questionnaires were returned, providing 354 research proposals,

quite equally distributed amongst the four macro-areas. Accounting for a few changes in the original list of participants, 112 researchers were invited to participate in the second round, 75 of whom completed the on-line questionnaire. Response rates were 74.6% in the first round and 67.0% in the second (Table 1).

Table 1 – Response Rate for rounds 1 and 2.

Macro-area	Round 1		Round 2
	Response Rate	Research proposals	Response Rate
1 – Demographic change	80.0%	104	
2 – Globalization	76.9%	72	
3 – New technologies	65.6%	82	
4 – Chemical and biological agents	75.8%	96	
Total	**74.6%**	**354**	**67.0%**

Table 2 shows the geographical distribution of respondents. All the PEROSH member institutes contributed actively to the entire survey. In the first round, 41.5% of responses were from Central Europe, 33.0% from Northern Europe and 25.5% from Southern Europe. In the second round, the figures were substantially the same for Central Europe (41.3%), while they decreased to 26.7% for Northern Europe and increased to 32.0% for Southern Europe.

Table 2 – Geographical distribution of respondents for rounds 1 and 2.

Country	Round 1 (n=94)		Round 2 (n=75)	
	Frequency	Per cent	Frequency	Per cent
Northern Europe	31	33.0	20	26.7
Central Europe	39	41.5	31	41.3
Southern Europe	24	25.5	24	32.0
Total	**94**	**100.0**	**75**	**100.0**

The research proposals underwent a process of classification based on the identification of keywords and recurrence of similar concepts. 16 RTs were identified and traced to the macro-area of reference according the structure of the EU-OSHA report. Each RT contained a variable number of priorities, totalling 67 RPs. Another 10 RPs, related to more transversal research issues and difficult to trace back to a specific RT were included in a special section named "Miscellaneous".

Table 3 shows the MV and SD calculated for each RT both in the general sample and by geographical distribution of respondents. Percentage response frequencies are also shown.

According to the analysis performed, the top five RTs were:

- *Older Workers*, with 3.90,
- *Nanomaterials* with 3.89,
- *Emerging Technological Devices* with 3.87,
- *Chemical agents* with 3.83,
- *Working conditions, working organization and job content* with 3.81.

The subsequent topics, down to the fourteenth place, obtained MV higher than 3.00. Only the last two RTs reached MV lower than 3.00 – *OSH consequences of markets integration* with 2.85 and *Electromagnetic Fields* with 2.59.

The comparison by geographical areas showed significant differences in the MV only for three RTs:

- *Women at work and gender aspects*, with a significantly higher score in Southern Europe (3.74) compared to Northern Europe (2.74) (Tamhane, p=0.031) and Central Europe (2.93) (Tamhane, p=0.026);
- *Nanomaterials*, where the MV for Southern Europe (4.36) is significantly higher than for Central Europe (3.69) (Tamhane, p=0.006);

- *Electromagnetic fields*, with a MV in Northern Europe (1.82) significantly lower than in Central Europe (2.92) (Bonferroni, p=0.012) and Southern Europe (2.83) (Bonferroni, p=0.042).

Furthermore, the analysis of frequencies pointed out that 90-95% of the sample evaluated moderately to extremely important the RTs in the higher-ranking positions, vouching for a strong consensus on such issues.

Table 4 displays the top five RPs in each macro-area according to MV obtained (see online supplementary material for the extended titles of research priorities and the complete list of descriptive statics).

In the macro-area related to Demographic change (12 RPs classified into 5 RTs), all the RPs obtained a MV between 3.22 and 3.88. Among these, six had a MV > 3.50 (2 in *Disabled workers*, 3 in O*lder Workers*, 1 in *Migrant workers*). The SD was between 0.92 and 1.21. The percentage frequencies for the medium-high level of importance (from 3=moderately important to 5=extremely important) ranged from a minimum of 75.4% (1 in *Women at work*) to a maximum of 92.6% (1 in *Disabled workers*). The percentage of "I don't know" in this macro-area was between 5% and 10%.

In the macro-area related to Globalization and the changing world of work (19 RPs classified into 4 RTs) MV varied between a minimum of 2.75 and a maximum of 3.81. Only the priority related to *Use and abuse of substances improving working performance* had a MV below 3.00. 10 RPs had a MV between 3.10 and 3.48 (1 in *Employment patterns and practices*, 1 in *OSH consequences of markets integration*, 3 in *Reorganisation processes* and 5 in *Working conditions*). 8 RPs obtained a MV between 3.52 and 3.81 (3 in *Employment patterns and practices*, 1 in *OSH consequences of markets integration*, 1 in *Reorganisation processes* and 3 in *Working conditions*). The SD was between 0.86 and 1.20. The percentage frequencies for

the medium-high level of importance (except for *Use and abuse of substances improving working performance* with 58.2%) ranged from 72.6% to 92.9%; in 12 out of 19 RPs, this percentage was higher than 80.6%. Few RPs received over 10% of "I don't know"; in one case, this percentage was 26. 7%.

In the macro-area related to Safe New Technologies (21 RPs classified into 5 RTs), there were only 3 priorities with a MV lower than 3.00, all included in the *Electromagnetic Fields* topic. 8 RPs had a MV varying between 3.00 and 3.50 (4 in *Emerging Technological Devices*, 3 in *Information and Communication Technology (ICT)* and 1 in *Nanomaterials*). 10 RPs had MV between 3.51 and 4.00 (6 in Nanomaterials, 2 in *ICT* and 2 in *Green Jobs*). Similarly, to the other macro-areas, the SD is between 0.98 and 1.47. As regards the percentage frequencies for the medium-high level of importance, it was below 80.0% in 5 RPs, while 13 reached values between 82.8% and 96.6%. For all the RPs in this macro-area, the percentage of "I don't know" is higher than 10%; in 14 cases, it ranged between 16.0% and 29.3%.

In the macro-area related to Chemical and biological agents (15 RPs classified into 2 RTs), MV varied between 2.84 and 3.63. 5 RPs had a MV higher than 3.50 (4 in *Chemical Agents* and 1 in *Biological Agents*); 2 RPs had a MV below 3.00 (1 in *Chemical Agents* and 1 in *Biological Agents*). For the remaining 8 RPs (3 in *Chemical Agents* and 5 in *Biological Agents*) MV was between 3.00 and 3.50. The SD was between 0.97 and 1.37. The percentage frequencies for the medium-high level of importance ranged for all RPs between 61.8% and 87.3%, with nine RPs with a percentage higher than 80.0%. In this macro-area, the percentage of "I don't know" was between 20% and 38.7%.

Table 3. General ranking of Research Topics. Descriptive statistics in total sample and by geographical distribution.

Rank	Research Topics	Macro-area	Total sample (N=75)					Northern Europe (N=20)		Central Europe (N=31)		Southern Europe (N=24)		Sig.
			n	Mean (SD)	0* (%)	1-2† (%)	3-5‡ (%)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	
1	Older workers (OW)	1	73	3.90 (0.82)	0.0	4.1	95.9	20	3.80 (0.77)	30	3.83 (0.87)	23	4.09 (0.79)	ns
2	Nanomaterials (ENM)	3	63	3.89 (0.95)	0.0	11.1	88.9	15	3.53 (1.30)	26	3.69 (0.84)	22	4.36 (0.58)	0.015; SE>CE
3	Emerging technological devices (ETD)	3	71	3.87 (0.96)	0.0	7.0	93.0	17	3.71 (0.85)	31	4.03 (0.88)	23	3.78 (1.13)	ns
4	Chemical agents (CA)	4	64	3.83 (0.94)	0.0	10.9	89.1	17	3.59 (1.12)	26	3.96 (0.77)	21	3.86 (0.96)	ns
5	Working conditions, work organisation and job content (WC)	2	72	3.81 (1.03)	0.0	12.5	87.5	18	3.61 (1.15)	31	3.94 (1.00)	23	3.78 (1.00)	ns
6	Disabled and chronically sick workers (work disability prevention and return-to-work research)-(DCSW)	1	73	3.66 (0.96)	0.0	11.0	89.0	20	3.50 (0.83)	30	3.67 (0.99)	23	3.78 (1.04)	ns
7	Changing employment patterns and practices (CEPP)	2	69	3.65 (1.04)	0.0	14.5	85.5	19	3.32 (1.11)	30	3.77 (0.94)	20	3.80 (1.11)	ns
8	Information and Communication Technology (ICT)	3	69	3.58 (1.13)	1.4	14.5	84.1	17	3.12 (1.36)	29	3.90 (1.05)	23	3.52 (0.95)	ns
8	Biological agents (BA)	4	64	3.58 (0.97)	0.0	15.6	84.4	17	3.29 (1.21)	26	3.62 (0.98)	21	3.76 (0.70)	ns
10	Health inequalities and work – Vulnerable	1	71	3.48 (1.04)	0.0	16.9	83.1	20	3.55 (0.95)	29	3.31 (1.14)	22	3.64 (1.00)	ns

	workers (HIW)													
11	Migrant workers (MW)	1	71	3.45 (1.27)	2.8	16.9	80.3	18	3.89 (0.90)	30	3.03 (1.50)	23	3.65 (1.07)	ns
12	Green jobs (GJ)	3	70	3.44 (0.97)	0.0	12.9	87.1	18	3.33 (1.09)	30	3.37 (1.10)	22	3.64±0.66	ns
13	Enterprises' reorganisation processes (restructuring, mergers and acquisitions, downsizing, closure, outsourcing, delocalisation and reshoring) (ERP)	2	66	3.15 (1.23)	1.5	25.8	72.7	17	2.82 (1.19)	29	3.21 (1.26)	20	3.35 (1.23)	ns
14	Women at work and gender aspects (WW)	1	71	3.14 (1.28)	4.2	23.9	71.9	19	2.74 (1.45)	29	2.93 (1.39)	23	3.74 (0.69)	0.023; SE>NE; SE>CE
15	OSH consequences of markets integration based on the reduction of barriers to free movement of goods (OCMI)	2	62	2.85 (1.14)	3.2	29.1	67.7	14	2.43 (1.34)	27	2.81 (1.08)	21	3.19 (1.03)	ns
16	Electromagnetic fields (EMF)	3	61	2.59 (1.26)	6.5	41.0	52.5	17	1.82 (1.24)	26	2.92 (1.20)	18	2.83 (1.10)	0.013; NE<CE; NE<SE

* 0 = Not at all important

† 1-2 = Little and Slightly important

‡ 3-5 = Moderately to Extremely important

Table 4. Ranking of Research Priorities by Mean Value according to macro-area. Descriptive statistics in total sample and by geographical distribution.

	Research Priorities (RT)	Total (N=75)		Northern Europe (N=20)	Central Europe (N=31)	Southern Europe (N=24)
		3-5* (%)	Mean Values (SD)			
1 – DEMOGRAPHIC CHANGE						
1	**1.12** Disability prevention, return to work, longer working life **(DCSW)**	92.6	3.88 (0.92)	3.65 (0.86)	3.86 (0.95)	4.09 (0.92)
2	**1.3** Impacts of work organisation and job design on older workers' H&S **(OW)**	87.1	3.70 (1.01)	3.37 (1.01)	3.76 (0.87)	3.91 (1.15)
3	**1.1** Extended working lives, prolonged workplace exposures and lifelong exposure data **(OW)**	85.9	3.66 (1.03)	3.40 (1.10)	3.69 (0.93)	3.86 (1.08)
4	**1.8** Sustainable and inclusive OSH system for multi-ethnic workforce **(MW)**	85.7	3.57 (1.02)	3.63 (0.83)	3.46 (1.20)	3.65 (0.94)
5	**1.11** Impact of occupational risk factors on older workers with chronic diseases **(DCSW)**	83.6	3.55 (0.99)	3.39 (0.92)	3.54 (1.04)	3.71 (1.01)
2 – GLOBALIZATION						
1	**2.31** Working-time flexibilisation, health, wellbeing and productivity **(WC)**	92.9	3.81 (0.86)	3.68 (0.95)	3.76 (0.79)	4.00 (0.87)
2	**2.22** Prolonged precariousness and ageing workforce **(CEPP)**	88.1	3.78 (0.98)	3.44 † (1.10)	3.59 † (0.93)	4.27 † (0.77)
3	**2.17** Introduction of unsafe / unhealthy work equipment, materials and goods **(OCMI)**	92.4	3.68 (0.96)	3.88 (0.81)	3.43 (0.97)	3.90 (1.02)
4	**2.20** OSH management in crowdsourcing, internships, zero hours contracts **(CEPP)**	79.1	3.64 (1.20)	3.35 (1.22)	3.83 (1.07)	3.62 (1.36)
5	**2.15** Restructuring, practical interventions to reduce OSH risks and support wellbeing **(ERP)**	84.1	3.62 (0.96)	3.38 (0.96)	3.58 (0.76)	3.86 (1.15)
Q3 – NEW TECHNOLOGIES						
1	**3.32** NOAA, standardised sampling and measurement methods **(ENM)**	96.6	4.00 (0.92)	3.63 (1.26)	4.00 (0.80)	4.27 (0.63)

2	**3.33** NOAA, regulations, guidelines and good practices **(ENM)**	91.2	3.90 (1.08)	3.57 (1.51)	4.05 (0.92)	3.96 (0.90)
3	**3.34** NOAA risk assessment: toxicological evaluation and bio-monitoring programs **(ENM)**	89.7	3.81 (1.02)	3.47 (1.46)	3.71 (0.96)	4.14 (0.56)
4	**3.36** NOAA, physical and chemical properties, research data and knowledge transfer **(ENM)**	87.7	3.79 (1.16)	3.20 ‡ (1.37)	3.67 (1.20)	4.33 ‡ (0.66)
5	**3.41** Smart PPE and adaptive/wearable sensors, environment and workers' monitoring **(ICT)**	85.1	3.70 (1.10)	3.44 (1.20)	3.55 (1.09)	4.15 (0.93)
Q4 – CHEMICAL AND BIOLOGICAL AGENTS						
1	**4.64** Multiple chemical exposures and interactions between chemicals and other risks **(CA)**	84.7	3.63 (1.14)	3.47 (1.18)	3.61 (1.20)	3.79 (1.08)
2	**4.60** Sampling and detection devices for early detection of chemicals **(CA)**	84.5	3.62 (1.01)	3.63 (1.20)	3.57 (0.95)	3.68 (0.95)
2	**4.57** Measurement devices and methods for sampling and assessment of bio-aerosols **(BA)**	87.3	3.62 (1.16)	3.35 (1.37)	3.90 (0.91)	3.56 (1.20)
4	**4.61** Reliable, non-invasive biomarkers to measure occupational exposure to chemicals **(CA)**	83.3	3.56 (1.08)	3.53 (1.13)	3.62 (1.02)	3.50 (1.15)
5	**4.66** CMRs and sensitising substances, Exposure modelling, Job-Exposure Matrix (**CA)**	83.0	3.51 (1.03)	3.36 (1.08)	3.50 (1.10)	3.65 (0.93)
MISCELLANEOUS						
1	**5.69** Translation of OSH research evidence into practical tools	86.1	3.82 (1.17)	3.63 (1.21)	3.90 (1.21)	3.87 (1.10)
2	**5.72** OSH implementation in micro, Small and Medium Enterprises (SMEs)	85.1	3.61 (1.17)	3.56 (1.20)	3.75 (0.97)	3.48 (1.40)
3	**5.75** Addressing OSH since the design stage in research on new technologies	75.0	3.33 (1.31)	2.94 (1.39)	3.66 (1.08)	3.16 (1.50)
4	**5.68** Tools and methods to support European companies' prevention needs	73.1	3.21 (1.25)	2.88 (1.26)	3.36 (1.25)	3.26 (1.25)
5	**5.71** Health inequalities among employees, workplaces, regions, sectors of employment	64.4	2.85 (1.11)	3.20 (1.01)	2.62 (1.20)	2.89 (1.02)

*3-5 = Moderately to Extremely important

† 0.009; SE>NE; SE>CE

‡ 0.015; SE>NE

DISCUSSION

The high level of participation in both rounds, with a high number of relevant research proposals submitted in the first, confirms the interest of the research community in being directly involved in the definition of research agendas and planning activities.

As regards the results, it is useful to note that 14 out of the 16 RTs coming from the first round of Delphi questionnaire obtained a MV between 3.14 and 3.90, showing a positive evaluation in terms of importance. In particular, the first 12 RTs were rated ≥ 3 by at least 80% of the sample.

Ageing of the workforce and return to work looks to be the core issue in the area of Demographic change, underlining the importance of answering the needs of prolonging working life in a healthy and productive way. On the other hand, topics still included in the area of Demographic change, which had a consolidated and relevant space within recent OSH agendas, such as vulnerable workers in general, migrant workers and gender issues seem to attract a lower interest in terms of OSH research.

In the area of Technological Innovation, the most relevant topic is that related to nanotechnologies. Nevertheless, the analysis by geographical distribution shows a specific trend: in fact, this topic has the highest MV in Southern Europe, while its importance is significantly lower in the other geographical areas.

It is interesting to note that in the macro-area related to Technological innovation, *Emerging technological devices* appears, for the first time with this study, as an autonomous OSH research topic. As a matter of fact, the general topic obtained a higher rating than the specific priorities traced under this heading. This might be due to the perception that this kind of devices can have relevant long-term impacts in terms of innovation and sustainable growth, while the specific research priorities actually identified are still linked to small and

very specific projects, only precursors to wider future developments. It must be also noted that the level of importance attributed to this topic overtakes that of two other topics showing a much steadier link between H&S and technological innovation, such as *ICT* and *Green Jobs*.

The lower importance assigned to *ICT* as a discrete topic might be due to the inclusion of the risks related to ICT as such into some other topics, like work organization, job content and ageing. On the other hand, green jobs still look not to have a full relevance within OSH issues. In fact, the priorities included in this topic highlight the need to develop a better knowledge and to define the effective relevance of the risks for workers' H&S related to these technologies.

Enterprises' reorganisation processes and *OSH consequences of markets integration* are the two RTs that received the lowest rating among those included in the macro-area of Globalization. For the first, this might be due to the specific focus of research on actions to improve risk management and reduce risk exposure during these processes, rather than studying the impact of exposures, whose effects are already well known. For the second, notwithstanding the low MV obtained by the RT, the two RPs included received a much higher evaluation: the reason for this might be due to an unclear wording of the RT, while the more detailed definition of the priorities supported a better comprehension of the related OSH issues.

Among the RTs with the lowest rating, *Women at work* and *Electromagnetic fields* are also included. The low ranking of *Women at work* is in line with previous findings, which highlighted a relevant attention to the issue in terms of OSH implementation but not as an autonomous research topic.[23-25] However, the analysis by geographical distribution suggests some new food for thought, worthy of further study. Unlike other regions,

Southern Europe ranked both the RT and the related RPs amongst the highest in order of importance.

As regards *Electromagnetic Fields*, there is a clear contrast with previous studies. In fact, in the studies carried out by EU-OSHA to identify OSH research priorities, there was a strong emphasis on the need to explore the effects of the new applications of this technology.[4, 7] On the contrary, the present study shows a significant reduction in interest for this issue, with a MV lower than 3 in all the geographical regions and even lower than 2 in Northern Europe.

Among the 77 RPs included in the second round of the Delphi survey, 65 were rated with a MV higher than 3 (moderately important), recognizing a medium-high level of importance to the RP. This level of importance was assigned by at least 80% of the respondents in 44 RPs.

Some very new issues appeared amongst the top priorities. Particular importance has been attached to OSH management in new forms of employment (e.g. crowdsourcing, internships, zero hours contracts); OSH impacts of innovation and new ways of working (i.e. tele-work, e-work, boundary less work); H&S in human-computer interaction; and, the introduction of unsafe and unhealthy work equipment following the reduction of barriers to the free movement of goods.

Finally, high importance was attributed to two transversal priorities, related to the translation of research results into practical and effective tools, and to the support for OSH implementation in micro, Small and Medium Enterprises (SMEs).

Strengths and limitations

The methodological approach used in the present study, develops previous experiences in an innovative way, by defining a path of full involvement of the research community in each

step of the priority setting process, from the identification of priorities to the assessment of their relevance and their ranking by level of importance.

The involvement of a European network of OSH research institutions has ensured not only a good representation of competencies and resources available across the network member institutes, but also a wide geographical coverage that made it possible to analyse the different level of perception and awareness of the several issues in different European regions.

On the other hand, the attitude of researchers to promote their own research activities as priorities represents a limitation of the study, particularly for the development of future research agendas, which goes beyond the boundaries of sectoral research and needs to be highly interdisciplinary to meet the objectives of innovative and sustainable growth set by the European research strategy.

These limitations have been amended, at least partially, by the identification of well-defined fields of interest through the reference to the four macro-areas of the EU-OSHA report.[7] In addition, the decision to invite the overall sample to assess the level of importance of the entire set of priorities, and not only of those included in their macro-area of expertise, allowed reduction of the importance of the single respondent's evaluations and consequently decreased the impact of such a bias.

Comparison with previous studies

This study ratifies the central role of some RTs whose relevance was already widely acknowledged by the literature. On the other hand, topics related to gender issues and electromagnetic fields, although still receiving high attention at policy level, show a lower demand for research. Furthermore, the absence of any reference to the themes of violence

and harassment at work among the researchers' proposals must be underlined as a major difference from the 2013 EU-OSHA study.

The study identifies some innovative RTs that are not reflected in previous studies, such as *Emerging Technological Devices* and *OSH consequences of markets integration*. Some new elements are also highlighted among RPs, such as new forms of work delivery (e.g. crowdsourcing, e-work, zero-hours contracts), which were only hinted in the 2013 EU-OSHA study.

Conclusions

This study allowed the identification and assessment of the relevance of a well-organized and fine-tuned set of RPs suitable for drawing up a proper agenda for further development of OSH research. This has been achieved through a process entirely shared with a large, geographically representative and qualified panel of European OSH researchers.

Therefore, it offers an effective representation of the OSH research community views on the needs for future research developments, able to contributing to the achievement of the innovation and sustainable growth objectives set by the European strategies.

Those priorities receiving a positive evaluation with a high level of consensus may represent the backbone of a reliable set of OSH research issues in the settlement of the 2020-2030 European Research Agenda.

Figure 1 – The modified Delphi process adopted in the study.

Competing Interests

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

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Data sharing

All available data have been published within the paper and the annex.

Contributorship statement

SI promoted the project and the work. DG, BMR, and SI each made substantial contributions to the conception and design of the study protocol. DG, BMR, MM, PE, ME and PP contributed to the collection and elaboration of data. BRM and GB designed and performed the data analysis. BMR, MM and AV wrote the manuscript. DG, PE, ME, PP and SI provided critical inputs regarding the discussion and conclusions of the manuscript. DG and SI revised the final version of the manuscript. SI approved the final version of the manuscript to be published.

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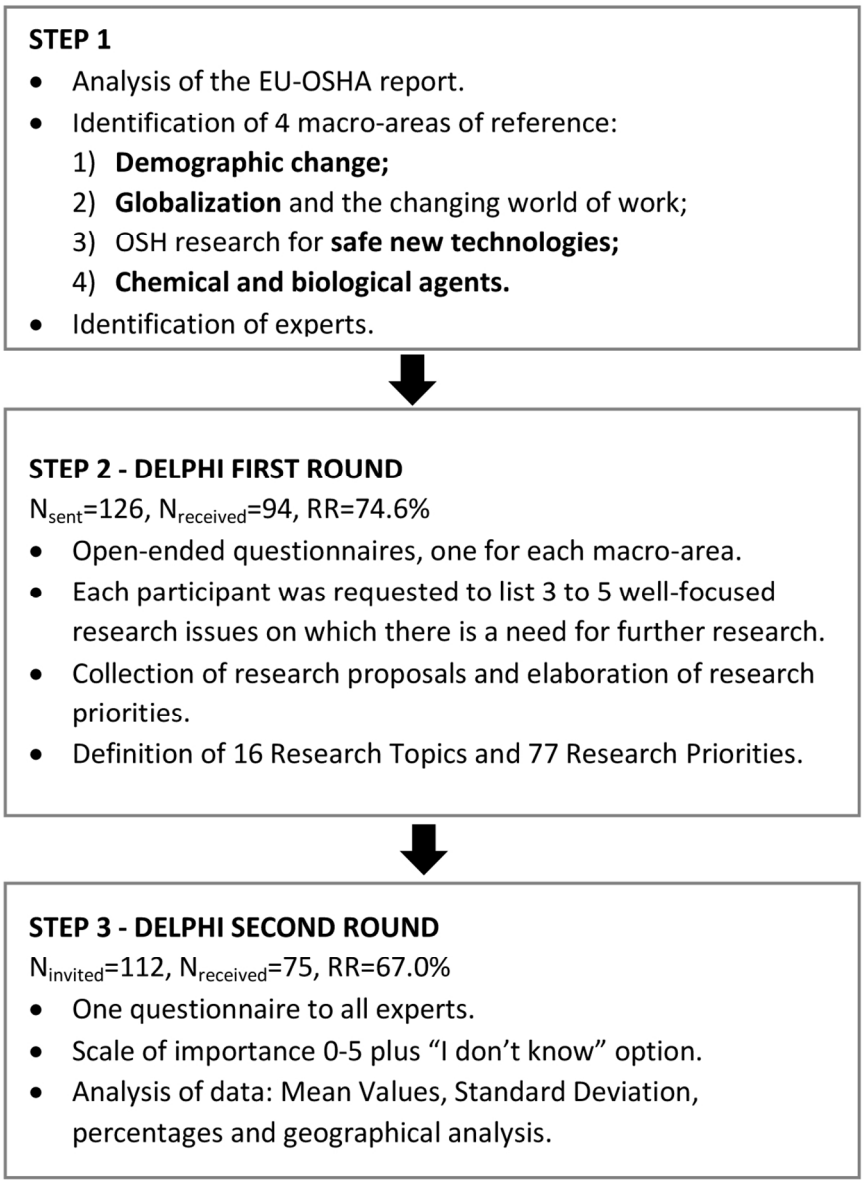

Figure 1 – The modified Delphi process adopted in the study.

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SUPPLEMENTARY TABLE - List of Research Topics and Research Priorities. Descriptive statistics in total sample and by geographical distribution.

MACROAREA ***RESEARCH TOPICS*** Research Priorities	**Total sample (N=75)**					**Northern Europe (NE) (N=20)**		**Central Europe (CE) (N=31)**		**Southern Europe (SE) (N=24)**		**Sig.**	**POST HOC P<0.05**
	n	**Mean Value(SD)**	**0* (%)**	**1-2** (%)**	**3-5*** (%)**	**n**	**Mean Value(SD)**	**n**	**Mean Value(SD)**	**n**	**Mean Value(SD)**		
1 – DEMOGRAPHIC CHANGE													
1. OLDER WORKER	***73***	***3.90(0.82)***	***0.0***	***4.1***	***95.9***	***20***	***3.80(0.77)***	***30***	***3.83(0.87)***	***23***	***4.09(0.79)***	***ns***	
1.1 Extended working lives and prolonged workplace exposures to physical, chemical, biological and psychosocial hazards: development of techniques and models to collect lifelong exposure data and to assess the effects of such exposures on workers' H&S.	71	3.66(1.03)	0.0	14.1	85.9	20	3.40(1.10)	29	3.69(0.93)	22	3.86(1.08)	ns	
1.2 Investigate the causes of early departure from work and the potential OSH measures (e.g. products, support, adaptation and incentives) to improve the work environment, and support, rehabilitate and retain ageing workers over a longer working life.	69	3.51(1.02)	0.0	15.9	84.1	19	3.32(1.11)	28	3.64(0.83)	22	3.50(1.19)	ns	
1.3 Identify the potential impacts of work organisation and job design on older workers' H&S and the ways in which these can support individual older workers. Specific areas of interest include MSDs, stress, and interventions for SMEs.	70	3.70(1.01)	0.0	12.9	87.1	19	3.37(1.01)	29	3.76(0.87)	22	3.91(1.15)	ns	
1.4 Investigate the role of HRM and improve their management practices on employee and organisational level outcomes, such as wellbeing/work ability, work engagement, resilience, retirement intentions, actual retirement transition and productivity.	67	3.37(1.03)	0.0	16.4	83.6	18	3.17(1.10)	28	3.64(0.99)	21	3.19(0.98)	ns	
2. WOMEN AT WORK AND GENDER ASPECTS	***71***	***3.14(1.28)***	***4.2***	***23.9***	***71.9***	***19***	***2.74(1.45)***	***29***	***2.93(1.39)***	***23***	***3.74(0.69)***	***0.023***	***SE>NE SE>CE***
1.5 Investigate and develop understanding of gender differences in occupational risks, including new and emerging risks.	71	3.30(1.21)	4.2	16.9	78.9	19	3.16(0.96)	29	3.03(1.52)	23	3.74(0.81)	ns	
1.6 Investigate and reduce negative effects on women's safety behaviours, health and productivity of the interaction between work organisation and work environment, job insecurity, women's work-life balance and women's physiological conditions.	69	3.22(1.14)	1.4	23.2	75.4	18	2.72(1.13)	28	3.36(1.25)	23	3.44(0.90)	ns	
3. MIGRANT WORKERS	***71***	***3.45(1.27)***	***2.8***	***16.9***	***80.3***	***18***	***3.89(0.90)***	***30***	***3.03(1.50)***	***23***	***3.65(1.07)***	***ns***	
1.7 Identify OSH issues for workers living away from their home country, for example low pay, poor working conditions, and poor H&S conditions.	71	3.37(1.16)	1.4	21.1	77.5	20	3.40(0.88)	28	3.32(1.25)	23	3.39(1.31)	ns	
1.8 Understand and address the impact on OSH management of linguistic, cultural and knowledge diversity in multicultural workplaces: how to develop a sustainable and inclusive OSH	70	3.57(1.02)	1.4	12.9	85.7	19	3.63(0.83)	28	3.46(1.20)	23	3.65(0.94)	ns	

system for multinational and multi-ethnic workforces.													
4. HEALTH INEQUALITIES AND WORK – VULNERABLE WORKERS	***71***	***3.48(1.04)***	***0.0***	***16.9***	***83.1***	***20***	***3.55(0.95)***	***29***	***3.31(1.14)***	***22***	***3.64(1.00)***	***ns***	
1.9 Investigate the extent of problems facing vulnerable workers using, for example, longitudinal studies, sector or group specific studies, comparative studies between countries, taking into account the impact of social determinants.	68	3.35(1.10)	0.0	22.1	77.9	20	3.30(1.26)	26	3.31(1.05)	22	3.46(1.06)	ns	
1.10 Investigate the factors that could improve the situation for vulnerable workers using, for example, workplace intervention studies and individual solutions.	69	3.32(1.01)	0.0	18.8	81.2	20	3.15(0.99)	27	3.37(0.88)	22	3.41(1.18)	ns	
5. DISABLED AND CHRONICALLY SICK WORKERS (WORK DISABILITY PREVENTION AND RETURN-TO-WORK RESEARCH)	***73***	***3.66(0.96)***	***0.0***	***11.0***	***89.0***	***20***	***3.50(0.83)***	***30***	***3.67(0.99)***	***23***	***3.78(1.04)***	***ns***	
1.11 Working with disability (chronic degenerative diseases, oncological, neurodegenerative, dysmetabolic conditions): assess the impact of occupational risk factors on older workers with chronic diseases and define interventions to reduce time off work.	67	3.55(0.99)	0.0	16.4	83.6	18	3.39(0.92)	28	3.54(1.04)	21	3.71(1.01)	ns	
1.12 Investigate ways and tools to prevent disability and to facilitate return to work in order to promote a longer working life, including adaptation of the workplace and work arrangements.	68	3.88(0.92)	0.0	7.4	92.6	17	3.65(0.86)	29	3.86(0.95)	22	4.09(0.92)	ns	
2 – GLOBALIZATION AND THE CHANGING WORLD OF WORK													
6. ENTERPRISES' REORGANISATION PROCESSES (RESTRUCTURING, MERGERS AND ACQUISITIONS, DOWNSIZING, CLOSURE, OUTSOURCING, DELOCALISATION AND RESHORING)	***66***	***3.15(1.23)***	***1.5***	***25.8***	***72.7***	***17***	***2.82(1.19)***	***29***	***3.21(1.26)***	***20***	***3.35(1.23)***	***ns***	
2.13 Understand the effects of geographical relocation of enterprises (delocalisation and reshoring to and from low wage countries) on workers' H&S and local health services in the EU.	62	3.10(1.00)	0.0	27.4	72.6	14	2.93(0.83)	26	3.00(1.02)	22	3.32(1.09)	ns	
2.14 Foster the emergence of a new approach to organisational change which allows enterprises managers to face, understand and overcome the negative impacts of restructuring on motivation, well-being and health of employees.	61	3.48(1.09)	0.0	21.3	78.7	17	3.06(0.66)	25	3.52(1.12)	19	3.79(1.27)	0.046	SE>NE
2.15 Identify practical interventions to reduce OSH risks and to support employees' wellbeing during restructuring.	63	3.62(0.96)	0.0	15.9	84.1	16	3.38(0.96)	26	3.58(0.76)	21	3.86(1.15)	ns	
2.16 Further improve knowledge on restructuring impact on risk factors (including psychosocial) for workers' H&S.	62	3.44(1.07)	0.0	16.1	83.9	14	3.21(1.12)	27	3.56(0.89)	21	3.43(1.25)	ns	
7. OSH CONSEQUENCES OF MARKET INTEGRATION BASED ON THE REDUCTION OF BARRIERS TO FREE MOVEMENT OF GOODS	***62***	***2.85(1.14)***	***3.2***	***29.1***	***67.7***	***14***	***2.43(1.34)***	***27***	***2.81(1.08)***	***21***	***3.19(1.03)***	***ns***	
2.17 Assess and reduce the risk of introducing unsafe and unhealthy	66	3.68(0.96)	0.0	7.6	92.4	16	3.88(0.81)	30	3.43(0.97)	20	3.90(1.02)	ns	

work equipment, materials and goods into EU manufacturing processes and workplaces.													
2.18 OSH research contribution to the development of policies ensuring the trade of goods produced according to globally shared standards for the protection of workers' H&S.	61	3.43(1.12)	0.0	16.4	83.6	14	3.57(1.16)	29	3.35(1.08)	18	3.44(1.20)	ns	
8. CHANGING EMPLOYMENT PATTERNS AND PRACTICES	***69***	***3.65(1.04)***	***0.0***	***14.5***	***85.5***	***19***	***3.32(1.11)***	***30***	***3.77(0.94)***	***20***	***3.80(1.11)***	***ns***	
2.19 Precarious work and job insecurity: better understand and address effects on workers' H&S.	67	3.55(1.00)	0.0	14.9	85.1	17	3.24(0.97)	28	3.57(1.03)	22	3.77(0.97)	ns	
2.20 OSH management in new forms of employment (crowdsourcing, internships, zero hours contracts).	67	3.64(1.20)	0.0	20.9	79.1	17	3.35(1.22)	29	3.83(1.07)	21	3.62(1.36)	ns	
2.21 Impact of precarious jobs on work-life balance.	67	3.46(1.06)	0.0	19.4	80.6	18	3.17(1.04)	27	3.48(1.01)	22	3.68(1.13)	ns	
2.22 Impact of prolonged precariousness on health conditions, wellbeing and quality of life of an ageing workforce.	67	3.78(0.98)	0.0	11.9	88.1	18	3.44(1.10)	27	3.59(0.93)	22	4.27(0.77)	0.009	SE>NE SE>CE
9. WORKING CONDITIONS, WORK ORGANISATION AND JOB CONTENT	***72***	***3.81(1.03)***	***0.0***	***12.5***	***87.5***	***18***	***3.61(1.15)***	***31***	***3.94(1.00)***	***23***	***3.78(1.00)***	***ns***	
2.23 Identify best work organisation practices to deal with health effects of an increasingly sedentary workforce (e.g. obesity and Musculo-Skeletal Disorders - MSDs).	69	3.41(1.10)	0.0	18.8	81.2	19	3.11(1.24)	29	3.62(1.18)	21	3.38(0.81)	ns	
2.24 Identify and address consequences on OSH of innovation and new ways of working, such as remote working practices (tele-work, e-work, boundary less work).	68	3.62(1.07)	0.0	17.6	82.4	17	3.06(1.09)	30	3.90(0.92)	21	3.67(1.11)	0.037	CE>NE
2.25 Find a balance between the need of enhancing employees' control over their work practices and the increasing adoption of Enterprise Resource Planning (ERP) systems.	55	3.13(1.02)	0.0	27.3	72.7	13	2.85(0.80)	26	3.15(1.22)	16	3.31(0.79)	ns	
2.26 Assessment of methods to improve management of psychosocial risks and promotion of psychosocial safety climate in ever increasingly competitive work environments.	67	3.52(1.05)	0.0	16.4	83.6	16	3.38(1.03)	29	3.62(1.08)	22	3.50(1.06)	ns	
2.27 Assessment of work-related stress influence in companies (workers' health, productivity, etc.).	69	3.45(0.98)	0.0	15.9	84.1	18	3.22(0.81)	29	3.55(0.87)	22	3.50(1.23)	ns	
2.28 Use and abuse of substances improving working performance and consequences on OSH.	67	2.75(1.12)	0.0	41.8	58.2	17	2.18(0.88)	28	2.86(1.18)	22	3.05(1.09)	0.041	SE>NE
2.29 Impact of mobile work on workers' physical and psychosocial health.	67	3.25(1.09)	0.0	23.9	76.1	17	2.82(0.88)	29	3.52(1.06)	21	3.24(1.22)	ns	
2.30 Management of OSH risks in multi-location work.	66	3.29(1.09)	1.5	21.2	77.3	17	2.94(1.09)	29	3.38(1.15)	20	3.45(1.00)	ns	
2.31 Better understand and address effects of working-time flexibilisation (long working hours and shift work) on health, wellbeing and productivity of the working population (specific attention should to be paid to vulnerable workers).	70	3.81(0.86)	0.0	7.1	92.9	19	3.68(0.95)	29	3.76(0.79)	22	4.00(0.87)	ns	
3 – OSH RESEARCH FOR SAFE NEW TECHNOLOGIES													
10. NANOMATERIALS	***63***	***3.89(0.95)***	***0.0***	***11.1***	***88.9***	***15***	***3.53(1.30)***	***26***	***3.69(0.84)***	***22***	***4.36(0.58***	***0.015***	***SE>CE***
3.32 Develop standardised sampling and measurement methods to quantify and characterise exposure to NOAA.	58	4.00(0.92)	1.7	1.7	96.6	16	3.63(1.26)	20	4.00(0.80)	22	4.27(0.63)	ns	

3.33 Develop regulations, guidelines and good practices for safely working with NOAA.	57	3.90(1.08)	1.8	7.0	91.2	14	3.57(1.51)	21	4.05(0.92)	22	3.96(0.90)	ns	
3.34 Improve risk assessment for workers exposed to NOAA (toxicological evaluation, studies of effects on human and biological systems and development of bio-monitoring programs).	58	3.81(1.02)	1.7	8.6	89.7	15	3.47(1.46)	21	3.71(0.96)	22	4.14(0.56)	ns	
3.35 Define Occupational Exposure Limits (OEL) for NOAA.	59	3.63(1.20)	1.6	15.3	83.1	15	3.13(1.51)	22	3.59(1.26)	22	4.00(0.76)	ns	
3.36 Improve research data and knowledge transfer on physical and chemical properties of NOAA to define the best set of properties for the cause-effect relationship.	57	3.79(1.16)	1.8	10.5	87.7	15	3.20(1.37)	21	3.67(1.20)	21	4.33(0.66)	0.015	SE>NE
3.37 Improve risk management tools for exposure to NOAA.	59	3.70(1.10)	1.7	11.9	86.4	16	3.38(1.20)	21	3.48(1.17)	22	4.14(0.83)	0.030	SE>NE SE>CE
3.38 Develop an information gathering approach for registration and toxicity testing for fibrous advanced materials.	53	3.57(1.07)	1.9	13.2	84.9	14	3.43(1.40)	21	3.76(1.00)	18	3.44(0.86)	ns	
11. GREEN JOBS	***70***	***3.44(0.97)***	***0.0***	***12.9***	***87.1***	***18***	***3.33(1.09)***	***30***	***3.37(1.10)***	***22***	***3.64(0.66)***	***ns***	
3.39 Better understand OSH implications in the Green Economy (e.g. green biotechnologies and green construction, renewable energies, waste management and environmental bioremediation) through data collection and scientific analysis on risk exposure.	65	3.57(0.98)	0.0	9.2	90.8	18	3.44(0.78)	25	3.44(1.16)	22	3.82(0.91)	ns	
3.40 Improve the identification and assessment of biological risks in the field of biofuel production (biomasses production, biogas plants, organic waste recovery), including the hazards related to the use of biotechnologies.	59	3.51(1.02)	0.0	15.3	84.7	18	3.67(0.69)	22	3.18(1.26)	19	3.74(0.93)	ns	
12. INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)	***69***	***3.58(1.13)***	***1.4***	***14.5***	***84.1***	***17***	***3.12(1.36)***	***29***	***3.90(1.05)***	***23***	***3.52(0.95)***	***ns***	
3.41 Development of smart Personal Protective Equipment (PPE) and adaptive/wearable sensors for the monitoring of environmental conditions and workers' physiological parameters.	67	3.70(1.10)	0.0	14.9	85.1	18	3.44(1.20)	29	3.55(1.09)	20	4.15(0.93)	ns	
3.42 Assessing the effects and impact of Information and Communication Technology (ICT) on workers' H&S, quality of working life and work-life balance.	67	3.36(1.08)	0.0	22.4	77.6	18	3.11(1.08)	28	3.79(1.07)	21	3.00(0.95)	0.013	CE>SE
3.43 Legal and ethical issues of employee monitoring and collected data protection.	66	3.38(1.16)	1.5	15.2	83.3	18	3.28(1.13)	28	3.50(1.20)	20	3.30(1.17)	ns	
3.44 Data Security and workers' safety in the Internet of Things (networks of physical objects that are embedded with the ability to exchange data, to interoperate with existing network infrastructure and that can be controlled remotely).	64	3.39(1.35)	0.0	28.1	71.9	16	2.94(1.65)	28	3.75(1.24)	20	3.25(1.16)	ns	
3.45 H&S factors in the design and engineering of multimodal human-computer interaction and interaction devices.	64	3.55(1.02)	0.0	17.2	82.8	16	3.13(1.03)	28	3.75(0.97)	20	3.60(1.05)	ns	
13. ELECTROMAGNETIC FIELDS	***61***	***2.59(1.26)***	***6.5***	***41.0***	***52.5***	***17***	***1.82(1.24)***	***26***	***2.92(1.20)***	***18***	***2.83(1.10)***	***0.013***	***NE<CE***

													NE<SE
3.46 Investigation of interaction mechanisms of magnetic, electric and electromagnetic fields with biological systems.	57	2.97(1.31)	5.3	28.1	66.6	14	2.14(1.41)	24	3.17(1.09)	19	3.32(1.29)	0.023	NE<SE
3.47 Electromagnetic fields in the workplace from advanced systems used in wireless communication and diagnostic technologies: human exposure and safe interaction with implantable therapeutic devices.	58	2.97(1.32)	3.4	29.3	67.3	14	2.14(1.29)	24	3.29(1.23)	20	3.15(1.27)	0.030	NE<CE
3.48 Safety evaluation of long exposure to electromagnetic low level fields.	56	2.86(1.47)	8.9	32.2	58.9	12	2.00(1.35)	25	2.88(1.42)	19	3.37(1.42)	0.035	NE<SE
14. EMERGING TECHNOLOGICAL DEVICES	***71***	***3.87(0.96)***	***0.0***	***7.0***	***93.0***	***17***	***3.71(0.85)***	***31***	***4.03(0.88)***	***23***	***3.78(1.13)***	***ns***	
3.49 Increasing use of 3D Printing and its implications on OSH.	63	3.29(1.10)	0.0	22.2	77.8	16	3.25(0.93)	28	3.36(1.25)	19	3.21(1.03)	ns	
3.50 Ensure the full exploitation of opportunities and control of risks for workers' safety related to interaction between humans and robots.	64	3.48(1.20)	3.1	12.5	84.4	17	3.18(0.95)	28	3.86(1.01)	19	3.21(1.51)	ns	
3.51 OSH implication of Automated Guided Vehicles (AGV) and Drones.	62	3.29(1.22)	1.6	19.4	79.0	17	3.06(1.09)	27	3.37(1.25)	18	3.39(1.34)	ns	
3.52 OSH related to production, use and maintenance of battery powered devices, equipment and vehicles.	63	3.06(1.19)	3.2	25.4	71.4	16	2.81(1.05)	28	3.39(1.13)	19	2.79(1.32)	ns	
4 – CHEMICAL AND BIOLOGICAL AGENTS													
15. BIOLOGICAL AGENTS	***64***	***3.58(0.97)***	***0.0***	***15.6***	***84.4***	***17***	***3.29(1.21)***	***26***	***3.62(0.98)***	***21***	***3.76(0.70)***	***ns***	
4.53 Investigate the contribution of microbial debris to the occupational exposure to airborne microorganism and the role of microorganisms in the development or aggravation of adverse health effects.	46	3.20(1.19)	2.2	15.2	82.6	13	3.31(1.25)	19	3.26(1.05)	14	3.00(1.36)	ns	
4.54 Investigate occupational risks due to the use or production of Genetically Modified Organisms (GMOs) and Genetically Modified Microrganisms (GMMs).	55	2.84(1.37)	5.5	32.7	61.8	16	2.44(1.32)	21	3.14(1.35)	18	2.83(1.43)	ns	
4.55 By means of Personal Protective Equipments (PPEs), new antibiotics and vaccines development, ensure proper protection of European workers' health from emerging pathogens introduced (or reintroduced) by globalisation and climate change.	55	3.42(1.21)	0.0	20.0	80.0	15	3.00(1.25)	21	3.43(1.25)	19	3.74(1.10)	ns	
4.56 Identification of chemical markers and medical parameters for correlating the occupational exposure to biological agents.	53	3.32(1.25)	0.0	28.3	71.7	15	3.13(1.30)	21	3.38(1.16)	17	3.41(1.37)	ns	
4.57 Development of appropriate measurement devices and standardised methods for workplace sampling and assessment of exposure to bio-aerosols.	55	3.62(1.16)	0.0	12.7	87.3	17	3.35(1.37)	20	3.90(0.91)	18	3.56(1.20)	ns	
4.58 Analyses and hazard assessment of biological agents at workplaces with complex exposure situations.	58	3.43(1.03)	0.0	19.0	81.0	16	3.56(1.21)	24	3.46(0.93)	18	3.28(1.02)	ns	
4.59 Investigate effects of bioremediation technologies and biodegradable substances used to replace chemicals on workers' health.	54	3.35(0.97)	0.0	18.5	81.5	16	3.13(1.09)	21	3.38(0.97)	17	3.53(0.87)	ns	

16. CHEMICAL AGENTS	***64***	***3.83(0.94)***	***0.0***	***10.9***	***89.1***	***17***	***3.59(1.12)***	***26***	***3.96(0.77)***	***21***	***3.86(0.96)***	***ns***	
4.60 Improve sampling and detection devices in providing an early and reliable detection of chemicals.	58	3.62(1.01)	0.0	15.5	84.5	16	3.63(1.20)	23	3.57(0.95)	19	3.68(0.95)	ns	
4.61 Increase the availability of reliable and non-invasive biomarkers for measuring occupational exposure to chemical substances and their effects.	54	3.56(1.08)	0.0	16.7	83.3	15	3.53(1.13)	21	3.62(1.02)	18	3.50(1.15)	ns	
4.62 Develop the necessary "a priori" knowledge of chemicals safety to support the increase in the use of "safety by design" practices in the development of new materials or in the use of known materials in innovative ways.	55	3.47(1.15)	0.0	23.6	76.4	15	3.00(1.41)	21	3.71(0.96)	19	3.58(1.07)	ns	
4.63 Scrutinising existing Occupational Exposure Limits (OEL) and their harmonisation with regulatory models (REACH and European Food Safety Authority -EFSA) in order to better protect workers' health.	52	3.44(1.18)	0.0	23.1	76.9	14	3.50(0.94)	21	3.24(1.41)	17	3.65(1.06)	ns	
4.64 Deepen understanding of multiple chemical exposures and interactions between chemicals and other risk factors (e.g. shift work and physical agents).	59	3.63(1.14)	1.7	13.6	84.7	17	3.47(1.18)	23	3.61(1.20)	19	3.79(1.08)	ns	
4.65 Deepen understanding of the relationship between individual (genetic) disposition and susceptibility against chemicals.	56	2.89(1.29)	1.8	35.7	62.5	16	2.81(1.33)	22	2.59(1.26)	18	3.33(1.24)	ns	
4.66 Develop exposure modelling techniques for Carcinogenic, Mutagenic and Reprotoxic (CMR) and sensitising substances in order to construct a European Job-Exposure Matrix (JEM).	53	3.51(1.03)	0.0	17.0	83.0	14	3.36(1.08)	22	3.50(1.10)	17	3.65(0.93)	ns	
4.67 Study on trends and significant changes in use of chemical and biological agents in the workplace (including information provided by Market Analysis).	56	3.23(1.04)	0.0	26.8	73.2	15	3.33(0.98)	22	3.23(0.92)	19	3.16(1.26)	ns	
MISCELLANEOUS													
5.68 Develop tools and methods to support European companies to better address their specific prevention needs and build programmes to monitor and “secure” employees’ health.	67	3.21(1.25)	3.0	23.9	73.1	16	2.88(1.26)	28	3.36(1.25)	23	3.26(1.25)	ns	
5.69 From research to practice: translation of OSH research evidence into practical tools to be used at company level and identification of the best ways to reach workers.	72	3.82(1.17)	1.4	12.5	86.1	19	3.63(1.21)	30	3.90(1.21)	23	3.87(1.10)	ns	
5.70 Development of a cross EU H&S qualification.	66	2.55(1.26)	7.6	34.8	57.6	17	2.29(1.05)	29	2.52(1.53)	20	2.80(0.95)	ns	
5.71 Studies on polarisation of employees' occupational health resources in the labour market (between employees, workplaces, regions, sectors of employment) and prevention of processes leading to unequal distribution of health at various levels.	59	2.85(1.11)	1.7	33.9	64.4	15	3.20(1.01)	26	2.62(1.20)	18	2.89(1.02)	ns	
5.72 OSH implementation in micro, Small and Medium Enterprises (SMEs): develop methods and tools to exploit available data to locate, identify, characterise and better regulate ever changing SMEs.	67	3.61(1.17)	1.5	13.4	85.1	18	3.56(1.20)	28	3.75(0.97)	21	3.48(1.40)	ns	

5.73 Development of measurement techniques, assessment strategies and safety requirements for noise exposure in call centres.	62	2.36(1.22)	3.2	46.8	50.0	15	1.87(0.92)	28	2.54(1.29)	19	2.47(1.26)	ns	
5.74 Non-audible noise: perception, influence, exposure limits, measurement techniques, assessment strategies, sources in new technologies and safety requirements.	54	2.76(1.26)	5.6	33.3	61.1	14	1.79(1.05)	26	3.31(0.93)	14	2.71(1.44)	0.001	NE<CE
5.75 Develop knowledge, concepts, techniques and tools to foster a transdisciplinary approach to research on new technologies development, able to address OSH issues from the design stage.	64	3.33(1.31)	4.7	20.3	75.0	16	2.94(1.39)	29	3.66(1.08)	19	3.16(1.50)	ns	
5.76 Ultrasound on bioeffects and safety: evaluating cell alterations at both cell membrane and genetic level at non-cavitation regime.	41	2.15(1.37)	12.2	48.8	39.0	12	1.83(1.40)	17	1.94(1.35)	12	2.75(1.29)	ns	
5.77 Malodorous substances at the workplace: validating test systems determining unacceptable nuisance for Occupational Exposure Limits (OEL) setting purposes.	54	2.07(1.21)	7.4	55.6	37.0	13	1.39(0.96)	24	2.46(1.10)	17	2.06(1.35)	0.037	NE<CE

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The perspective of European researchers of national occupational safety and health institutes for contributing to a European research Agenda: a modified Delphi study

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ABSTRACT

Objectives

This study, developed within the frame of the Partnership for European Research on Occupational Safety and Health (PEROSH) joint research activities and based on the results achieved in the 2013 European Agency for Safety and Health at Work (EU-OSHA) study, is the first example of using the points of view of European occupational safety and health (OSH) researchers.

The objective is to identify priorities for OSH research that may contribute to the achievement of present and future sustainable growth objectives set by the European strategies.

Methods

The study was carried out using a modified Delphi method with a two round survey. Each round involved a panel of about 110 researchers representing the network member institutes was selected according to specific criteria, including the ownership of research expertise in at least one of the four macro-areas identified by the reference report developed by EU-OSHA in 2013.

Results

The study identified some innovative Research Topics (for example "*Emerging technological devices*" and "*OSH consequences of markets integration*"*)* and Research Priorities (for example *crowdsourcing, e-work, zero-hours contracts*) that are not reflected in previous studies of this nature.

The absence of any reference to violence and harassment at work among the researchers' proposals is a major difference from previous similar studies, while topics related to gender issues and electromagnetic fields show a lower importance.

Conclusions

The innovative design of a research priorities identification process, which takes advantage of a large, representative and qualified panel of European researchers allowed the definition of a number of research priorities able to support the inclusion of innovative OSH research issues in the scope of the next European Research Agenda.

Keywords: Delphi study, research priorities, OSH, PEROSH, European Agenda

ARTICLE SUMMARY

Strengths and limitations of this study

- This is the first OSH Research priorities setting study able to provide a reliable expression of the perspective of the European OSH Research Community together with an analysis of differences between European geographical areas thanks to the involvement of a wide, transdisciplinary and transnational panel of European highly qualified OSH Researchers from 12 preeminent European National Institutes.
- The study takes advantage of an innovative methodological path that integrates the top- down and bottom-up approaches in order to steer the Researchers' involvement in each step of the priority setting process towards the provision of feasible research priorities responding to 4 predetermined OSH research challenges identified by the European Agency for Safety and Health at Work (EU-OSHA) on the basis of the strategic objectives set at European level.
- A limitation of the study was represented by the possibility of researchers to promote their own research activities as priorities, which is inconsistent with the need of going beyond the boundaries of sectoral research and being highly interdisciplinary.
- Another limitation of the study was the composition of the researchers' panel, reflecting only the OSH competences related to the macro-themes shaped by the 4 challenges, devoid of the skills specific of correlated research fields that could be relevant for a broader assessment of the strategic and synergic impact of the priorities on the European research framework.

INTRODUCTION

Demographic changes, globalization and technological innovation, are continuously reshaping the world of work, with a direct impact on workers' health and safety.[1, 2] New occupational risk factors are emerging owing to the "introduction of new technologies, substances and work processes, changes in the structure of the workforce and the labour market, and new forms of employment and work organization".[3] Furthermore, changes in social or public perceptions and the development of scientific knowledge allow long-standing issues to be considered afresh or identified as emerging risks.[4] Despite the good results already achieved by the European occupational health and safety (OSH) approach in terms of outcomes or indicators (such as work injuries prevention), these changes require further efforts to allow the OSH system to be able to effectively improve prevention of work-related illness as well as accidents.[5] OSH research, thus, needs to maintain a pivotal role in the development of policies for the improvement of workers' health and safety, allowing the OSH system to identify and tackle emerging issues in a timely way.[6]

Actually, different European and national research agendas have already given relevant space to many of the issues highlighted by this study and this should ensure the capacity for a timely, efficient and effective use of available resources to address the challenges presented by the changing world of work.

With this aim, in 2013 the European Agency for Safety and Health at Work (EU-OSHA) developed a study to connect OSH research objectives with both the Europe 2020 strategy and the Horizon 2020 programme and their key objectives of 'smart, sustainable and inclusive growth' and 'excellent science — competitive industries — better society'.[7-9]

The study identified four major challenges, which OSH research should use to support the pursuit of these objectives, as well as the research priorities to tackle these challenges.

This study is the most recent in a series of national and European level studies started in the early 1990s to identify research priorities able to fill the OSH knowledge gaps caused by the changes in the world of work.[10]

A critical review of such studies, though, showed that at European level a methodical and structured elicitation of the researchers' view aimed at the identification of research gaps and a fine-tuning of well-defined research priorities has always been missing, even if it would be complementary and add significant value. In the majority of cases, researchers' involvement in the development of these studies was not the primary focus and in any case downstream of previous elaborations developed by selected teams of OSH experts.

Also, the findings of the 2013 EU-OSHA study, despite consultation with a larger panel of OSH experts (including researchers, in addition stakeholders and other OSH professionals), were strongly rooted on a preliminary and in-depth desk analysis carried out by a restricted team of experts.

The only European level study which saw a large and effective involvement of researchers (alongside other OSH experts) was based on a set of four Delphi surveys conducted by the EU-OSHA Risk Observatory between 2004 and 2006.[4, 11-13] Nevertheless, this study focused more on new and emerging risk factors than on real priorities for research, and its final output was the identification of general OSH issues to be addressed.[14]

On the other hand, there are a number of well-documented national studies aimed at supporting the drafting of OSH research strategies which, beside the participation of different experts (OSH professionals, OSH services, policy makers, social parties, etc.), provide a full and direct involvement of the researchers' community in the priorities setting process. Such experiences, mostly based on Delphi surveying methods, took place in the USA, Malaysia, UK, Netherlands and Italy. Some of these studies (Italy and Netherlands) also

provided a distinct representation of researchers' point of view.[15-20]

The importance of surveying the research community is based on the premise that researchers, as main actors of research activities, are in a strong position to provide a real time and realistic picture of the state of the art and to define what is currently missing to properly tackle the upcoming challenges, as long as they are able to look beyond their current research activity. Furthermore, a wide, substantive and full involvement of researchers in the process of identification of research priorities can assess their feasibility, according to the current scientific evidence, and their consistent integration into existing research activities. Therefore, a clear and accurate representation of the expectations of the research community representing a relevant number of European national research institutes can provide a useful starting point for a strategy planning process aiming to produce an OSH research agenda.[21, 22]

For this reason, in 2014 the Partnership for European Research on Occupational Safety and Health (PEROSH, a network of 12 OSH research institutes across Europe) approved the joint research project "Futures. Foresight and priority setting in OSH", led by the Italian National Institute for the Insurance against Work Accidents (INAIL) with the collaboration of the Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA, Germany), the National Institute for Research and Safety (INRS, France) and HSE's Health and Safety Laboratory (UK).

Starting from the challenges identified in the 2013 EU-OSHA study, [7] the "Futures" project aimed at providing an updated identification of research needs and at prioritizing them by the level of consensus among the researchers working in the network member institutes. To this end, it took advantage of the large number of multidisciplinary researchers working in the member institutes and of the good geographical coverage of the network itself. Unlike

previous European level studies focusing on foresight activities and using the Delphi method, this is the first one to include only researchers in the Delphi panel and to focus exclusively on the identification of research topics and priorities, which the OSH research community considers fundamental for an effective development and improvement of the OSH system management.

This study integrates the agenda made by decision makers with the view of researchers, by enriching the bottom-up process where researchers represent the primary source for the identification of future research priorities, and not only the final step for the assessment of proposals developed by a small number of experts.

The purpose of this study is to provide a timely contribution to the development of European OSH research agendas in order to allow their effective alignment with the needs arising from the world of OSH research. It offers a picture of the researchers' points of view, which may represent the baseline of a strategic planning process, which should subsequently include a wider community of stakeholders, such as social partners and decision makers. The study also needs to react to the increasing reductions in funds for OSH research, as priority-setting processes are critical in aligning research funding with evidence needs as well as in supporting an efficient allocation of limited resources available for research.

METHODS

The study was based on a two-round modified Delphi survey, which involved a panel of researchers from all PEROSH institutes. The project's leader and co-coordinators (Coordination Group) developed the methodological path and shared it with the PEROSH Steering Committee. The method used is illustrated in Figure 1.

The Delphi technique is a well-suited and accepted method for consensus building by using a series of questionnaires to collect data from a panel of selected subjects concerning a specific topic.[23, 24] Also, it is one of the most widely used techniques for priority setting in OSH.[10, 15-20]

The main features of the Delphi method (anonymity, iteration, controlled feedback, statistical "group response") make it more suitable than others to obtain the opinion of a panel of experts on a predetermined topic, especially when dealing with geographically dispersed participants[25], or when the information available on a given topic are incomplete or poor.[26]

In the present study, a modified Delphi method was adopted, by using four different questionnaires (one for each of the four macro areas included in the EU-OSHA report) with a well detailed and focused (though open-ended) question on a specific matter. The use of a modified Delphi study is considered an appropriate option when information concerning the project is already partially available.[27, 28]

Step 1 – Desk analysis

The first step consisted of an in-depth analysis of the EU-OSHA report "Priorities for occupational safety and health research in Europe: 2013-2020", aimed at updating OSH research priorities identified in 2005 and taking into account the latest developments in scientific knowledge, the changes in the world of work and the impact of recent trends on OSH. The report also considered the priorities and key objectives set in the Europe 2020 strategy and the Horizon 2020 programme.[7-9, 29]

The EU-OSHA report includes four macro-areas, which were taken as landmarks for the present study:

1. **Demographic change** – sustainable work for healthier and longer working lives.
2. **Globalization** and the changing world of work – OSH research contribution to sustainable and inclusive growth.
3. OSH research for **safe new technologies** as a prerequisite for sustainable growth.

4. Research into new or increasing occupational exposures to **chemical and biological agents** for the benefit of a smart and sustainable economy.

All the PEROSH institutes contributed to the study by providing contact persons. Their task was to identify 5 to 20 expert researchers from each institute to be included in the panel, according to the following selection criteria: specific research experience (at national and possibly also international levels) in one or more of the four macro-areas and a present or planned direct involvement in research activities related to the relevant macro-area. Contact persons were requested to ensure anonymity among participants, in order to reduce the impact of dominant individuals.

Step 2. Delphi questionnaire – First round

The first round took place between March and April 2015. For each macro-area, a specific open-ended electronic questionnaire was sent to a subpanel of researchers, selected by their area of expertise (Supplementary File 1). Some researchers were indicated as experts for more than one macro-area.

Considering the total number of experts identified, participants were asked to list, within their field of expertise, three to five well-focused research issues on which there is a need for further research.

Step 3. Delphi questionnaire – Second round

Starting from the research proposals returned at the end of the first round and using keywords and recurrences of concepts to group together similar issues and to reduce the total number of research proposals and to avoid repetition and overlapping, the Coordination Group elaborated a structured questionnaire divided into 16 “Research Topics” (RT), each one containing a list of consistent “Research Priorities” (RP). The identification of the RT was based on the main structure of the EU-OSHA report, reflecting the general

content of each macro-area. There were only few disagreements that were discussed among the study team in a face-to-face meeting.

Before the second round, a preliminary pilot test was performed to assess accessibility of the platform and comprehensibility of the research proposals as well as to estimate the duration of the interviews. The pilot study involved 16 participants identified within the Coordination Group institutes. Feedback and comments were taken into account in designing for the final version of the survey.

For the second round of consultation, which took place between February and March 2016, the questionnaire was sent to the entire sample of researchers involved in the project, irrespective of their area of expertise and of their active participation in the first round.

In this round, researchers were asked to rate the level of importance of each RP and RT considering whether it is addressing a real OSH research gap and the impact that OSH research might have in terms of the breadth of the workers' population affected and the severity of avoidable damages to health. The rating system was based on a scale of importance, from 0 (=not at all important) to 5 (=extremely important). The system provided also the "I don't know" option, allowing those researchers who felt not to have enough expertise on a specific item to abstain (Supplementary File 2).

The questionnaire was circulated in English through the dedicated web-based platform SurveyMonkey®; the researchers involved received an electronic invitation by email, directly generated by the system. Two reminder emails were sent, the second one informing of a one-week extension of the deadline to increase the response rate.

To reduce response biases, the system provided a randomization of the RP in each page and a reversed order of the pages for 50% of the sample. The page with the list of RT was excluded from any randomization process.

Ratings given in the second round were analysed by calculating Mean Values (MV) and Standard Deviation (SD) for each RP and each RT. Percentages were also calculated considering those attributing no importance at all (0) and grouping together those attributing a low level of importance (little - 1 - or slight importance - 2), and those attributing a medium-high level of importance (from moderate - 3 - to extreme - 5) to each RP and RT.

There are many criteria to establish the achievement of consensus. Among them, SD values and percentages have been used as "consensus indicators". In detail, the research team agreed that a good level of consensus was achieved when at least 50.0% of the responders attributed a medium to high level of importance to the item and the SD value was lower than 1.50. As all the topics and all the priorities, except for two, were consistent with this criteria, it was decided not to perform any further round.

It should also be considered that there are no firm rules to establish when consensus is achieved, but usually, the stricter the criteria, the more difficult it is to obtain consensus.[30] In addition, available scientific literature shows that repeated rounds may lead the respondents to fatigue and increased attrition;[31] this is why the number of rounds can be limited to two without affecting the quality of the results.[32, 33]

Keeping in mind the European Countries represented within the Network, a geographical classification of participants, based on a modified UN classification, was performed, grouping together Denmark, Finland, Norway and UK for Northern Europe; Austria, France, Germany, the Netherlands and Poland for Central Europe (Western and Eastern Europe were gathered together as Central Europe to assure a homogeneous representativeness of researchers in the sub-samples); and Italy and Spain for Southern Europe. MV for each RP and RT were calculated with respect to the geographical distribution; statistically significant differences

were evaluated by applying the Kruskal Wallis test; Post Hoc tests were used to assess which MV were significantly different from the others. The Post Hoc tests used were Bonferroni or Tamhane, depending on whether variances were homogeneous or non-homogeneous according to the Levene test. Significance was set at $p<0.05$. Data were analysed using SPSS Statistics V. 21 (SPSS. IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp, 2013).

RESULTS

In the first round of Delphi, 126 questionnaires were forwarded to 110 researchers; some researchers received more than one questionnaire as they were quoted as experts in more than one macro-area. 94 questionnaires were returned, providing 354 research proposals, quite equally distributed amongst the four macro-areas. Accounting for a few changes in the original list of participants, 112 researchers were invited to participate in the second round, 75 of whom completed the on-line questionnaire. Response rates were 74.6% in the first round and 67.0% in the second (Table 1).

Table 1 – Response Rate for rounds 1 and 2.

Macro-area	Round 1		Round 2
	Response Rate	Research proposals	Response Rate
1 – Demographic change	80.0%	104	
2 – Globalization	76.9%	72	
3 – New technologies	65.6%	82	
4 – Chemical and biological agents	75.8%	96	
Total	**74.6%**	**354**	**67.0%**

Table 2 shows the geographical distribution of respondents. All the PEROSH member institutes contributed actively to the entire survey. In the first round, 41.5% of responses were from Central Europe, 33.0% from Northern Europe and 25.5% from Southern Europe.

In the second round, the figures were substantially the same for Central Europe (41.3%), while they decreased to 26.7% for Northern Europe and increased to 32.0% for Southern Europe.

Table 2 – Geographical distribution of respondents for rounds 1 and 2.

Country	Round 1 (n=94)		Round 2 (n=75)	
	Frequency	Per cent	Frequency	Per cent
Northern Europe	31	33.0	20	26.7
Central Europe	39	41.5	31	41.3
Southern Europe	24	25.5	24	32.0
Total	**94**	**100.0**	**75**	**100.0**

The research proposals underwent a process of classification based on the identification of keywords and recurrence of similar concepts. 16 RTs were identified and traced to the macro-area of reference according the structure of the EU-OSHA report. Each RT contained a variable number of priorities, totalling 67 RPs. Another 10 RPs, related to more transversal research issues and difficult to trace back to a specific RT were included in a special section named “Miscellaneous”.

Table 3 shows the MV and SD calculated for each RT both in the general sample and by geographical distribution of respondents. Percentage response frequencies are also shown.

According to the analysis performed, the top five RTs were:

- *Older Workers*, with 3.90,
- *Nanomaterials* with 3.89,
- *Emerging Technological Devices* with 3.87,
- *Chemical agents* with 3.83,
- *Working conditions, working organization and job content* with 3.81.

The subsequent topics, down to the fourteenth place, obtained MV higher than 3.00. Only the last two RTs reached MV lower than 3.00 – *OSH consequences of markets integration* with 2.85 and *Electromagnetic Fields* with 2.59.

The comparison by geographical areas showed significant differences in the MV only for three RTs:

- *Women at work and gender aspects*, with a significantly higher score in Southern Europe (3.74) compared to Northern Europe (2.74) (Tamhane, p=0.031) and Central Europe (2.93) (Tamhane, p=0.026);
- *Nanomaterials*, where the MV for Southern Europe (4.36) is significantly higher than for Central Europe (3.69) (Tamhane, p=0.006);
- *Electromagnetic fields*, with a MV in Northern Europe (1.82) significantly lower than in Central Europe (2.92) (Bonferroni, p=0.012) and Southern Europe (2.83) (Bonferroni, p=0.042).

Furthermore, the analysis of frequencies pointed out that 90-95% of the sample evaluated moderately to extremely important the RTs in the higher-ranking positions, vouching for a strong consensus on such issues.

Table 4 displays the top five RPs in each macro-area according to MV obtained (see online Supplementary Table for the extended titles of research priorities and the complete list of descriptive statics).

In the macro-area related to Demographic change (12 RPs classified into 5 RTs), all the RPs obtained a MV between 3.22 and 3.88. Among these, six had a MV > 3.50 (2 in *Disabled workers*, 3 in O*lder Workers*, 1 in *Migrant workers*). The SD was between 0.92 and 1.21. The percentage frequencies for the medium-high level of importance (from 3=moderately important to 5=extremely important) ranged from a minimum of 75.4% (1 in *Women at*

work) to a maximum of 92.6% (1 in *Disabled workers*). The percentage of "I don't know" in this macro-area was between 5% and 10%.

In the macro-area related to Globalization and the changing world of work (19 RPs classified into 4 RTs) MV varied between a minimum of 2.75 and a maximum of 3.81. Only the priority related to *Use and abuse of substances improving working performance* had a MV below 3.00. 10 RPs had a MV between 3.10 and 3.48 (1 in *Employment patterns and practices*, 1 in *OSH consequences of markets integration*, 3 in *Reorganisation processes* and 5 in *Working conditions*). 8 RPs obtained a MV between 3.52 and 3.81 (3 in *Employment patterns and practices*, 1 in *OSH consequences of markets integration*, 1 in *Reorganisation processes* and 3 in *Working conditions*). The SD was between 0.86 and 1.20. The percentage frequencies for the medium-high level of importance (except for *Use and abuse of substances improving working performance* with 58.2%) ranged from 72.6% to 92.9%; in 12 out of 19 RPs, this percentage was higher than 80.6%. Few RPs received over 10% of "I don't know"; in one case, this percentage was 26. 7%.

In the macro-area related to Safe New Technologies (21 RPs classified into 5 RTs), there were only 3 priorities with a MV lower than 3.00, all included in the *Electromagnetic Fields* topic. 8 RPs had a MV varying between 3.00 and 3.50 (4 in *Emerging Technological Devices*, 3 in *Information and Communication Technology (ICT)* and 1 in *Nanomaterials*). 10 RPs had MV between 3.51 and 4.00 (6 in Nanomaterials, 2 in *ICT* and 2 in *Green Jobs*). Similarly, to the other macro-areas, the SD is between 0.98 and 1.47. As regards the percentage frequencies for the medium-high level of importance, it was below 80.0% in 5 RPs, while 13 reached values between 82.8% and 96.6%. For all the RPs in this macro-area, the percentage of "I don't know" is higher than 10%; in 14 cases, it ranged between 16.0% and 29.3%.

In the macro-area related to Chemical and biological agents (15 RPs classified into 2 RTs), MV varied between 2.84 and 3.63. 5 RPs had a MV higher than 3.50 (4 in *Chemical Agents* and 1 in *Biological Agents*); 2 RPs had a MV below 3.00 (1 in *Chemical Agents* and 1 in *Biological Agents*). For the remaining 8 RPs (3 in *Chemical Agents* and 5 in *Biological Agents*) MV was between 3.00 and 3.50. The SD was between 0.97 and 1.37. The percentage frequencies for the medium-high level of importance ranged for all RPs between 61.8% and 87.3%, with nine RPs with a percentage higher than 80.0%. In this macro-area, the percentage of "I don't know" was between 20% and 38.7%.

Table 3. General ranking of Research Topics. Descriptive statistics in total sample and by geographical distribution.

Rank	Research Topics	Macro-area	Total sample (N=75)					Northern Europe (N=20)		Central Europe (N=31)		Southern Europe (N=24)		Sig.
			n	Mean (SD)	0* (%)	1-2† (%)	3-5‡ (%)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	
1	Older workers (OW)	1	73	3.90 (0.82)	0.0	4.1	95.9	20	3.80 (0.77)	30	3.83 (0.87)	23	4.09 (0.79)	ns
2	Nanomaterials (ENM)	3	63	3.89 (0.95)	0.0	11.1	88.9	15	3.53 (1.30)	26	3.69 (0.84)	22	4.36 (0.58)	0.015; SE>CE
3	Emerging technological devices (ETD)	3	71	3.87 (0.96)	0.0	7.0	93.0	17	3.71 (0.85)	31	4.03 (0.88)	23	3.78 (1.13)	ns
4	Chemical agents (CA)	4	64	3.83 (0.94)	0.0	10.9	89.1	17	3.59 (1.12)	26	3.96 (0.77)	21	3.86 (0.96)	ns
5	Working conditions, work organisation and job content (WC)	2	72	3.81 (1.03)	0.0	12.5	87.5	18	3.61 (1.15)	31	3.94 (1.00)	23	3.78 (1.00)	ns
6	Disabled and chronically sick workers (work disability prevention and return-to-work research)-(DCSW)	1	73	3.66 (0.96)	0.0	11.0	89.0	20	3.50 (0.83)	30	3.67 (0.99)	23	3.78 (1.04)	ns
7	Changing employment patterns and practices (CEPP)	2	69	3.65 (1.04)	0.0	14.5	85.5	19	3.32 (1.11)	30	3.77 (0.94)	20	3.80 (1.11)	ns
8	Information and Communication Technology (ICT)	3	69	3.58 (1.13)	1.4	14.5	84.1	17	3.12 (1.36)	29	3.90 (1.05)	23	3.52 (0.95)	ns
8	Biological agents (BA)	4	64	3.58 (0.97)	0.0	15.6	84.4	17	3.29 (1.21)	26	3.62 (0.98)	21	3.76 (0.70)	ns
10	Health inequalities and work – Vulnerable	1	71	3.48 (1.04)	0.0	16.9	83.1	20	3.55 (0.95)	29	3.31 (1.14)	22	3.64 (1.00)	ns

	workers (HIW)													
11	Migrant workers (MW)	1	71	3.45 (1.27)	2.8	16.9	80.3	18	3.89 (0.90)	30	3.03 (1.50)	23	3.65 (1.07)	ns
12	Green jobs (GJ)	3	70	3.44 (0.97)	0.0	12.9	87.1	18	3.33 (1.09)	30	3.37 (1.10)	22	3.64±0.66	ns
13	Enterprises' reorganisation processes (restructuring, mergers and acquisitions, downsizing, closure, outsourcing, delocalisation and reshoring) (ERP)	2	66	3.15 (1.23)	1.5	25.8	72.7	17	2.82 (1.19)	29	3.21 (1.26)	20	3.35 (1.23)	ns
14	Women at work and gender aspects (WW)	1	71	3.14 (1.28)	4.2	23.9	71.9	19	2.74 (1.45)	29	2.93 (1.39)	23	3.74 (0.69)	0.023; SE>NE; SE>CE
15	OSH consequences of markets integration based on the reduction of barriers to free movement of goods (OCMI)	2	62	2.85 (1.14)	3.2	29.1	67.7	14	2.43 (1.34)	27	2.81 (1.08)	21	3.19 (1.03)	ns
16	Electromagnetic fields (EMF)	3	61	2.59 (1.26)	6.5	41.0	52.5	17	1.82 (1.24)	26	2.92 (1.20)	18	2.83 (1.10)	0.013; NE<CE; NE<SE

* 0 = Not at all important

† 1-2 = Little and Slightly important

‡ 3-5 = Moderately to Extremely important

Table 4. Ranking of Research Priorities by Mean Value according to macro-area. Descriptive statistics in total sample and by geographical distribution.

	Research Priorities (RP)	Total (N=75)		Northern Europe (N=20)	Central Europe (N=31)	Southern Europe (N=24)
		3-5* (%)	Mean Values (SD)			
1 – DEMOGRAPHIC CHANGE						
1	**1.12** Disability prevention, return to work, longer working life **(DCSW)**	92.6	3.88 (0.92)	3.65 (0.86)	3.86 (0.95)	4.09 (0.92)
2	**1.3** Impacts of work organisation and job design on older workers' health and safety **(OW)**	87.1	3.70 (1.01)	3.37 (1.01)	3.76 (0.87)	3.91 (1.15)
3	**1.1** Extended working lives, prolonged workplace exposures and lifelong exposure data **(OW)**	85.9	3.66 (1.03)	3.40 (1.10)	3.69 (0.93)	3.86 (1.08)
4	**1.8** Sustainable and inclusive OSH system for multi-ethnic workforce **(MW)**	85.7	3.57 (1.02)	3.63 (0.83)	3.46 (1.20)	3.65 (0.94)
5	**1.11** Impact of occupational risk factors on older workers with chronic diseases **(DCSW)**	83.6	3.55 (0.99)	3.39 (0.92)	3.54 (1.04)	3.71 (1.01)
2 – GLOBALIZATION						
1	**2.31** Working-time flexibilisation, health, wellbeing and productivity **(WC)**	92.9	3.81 (0.86)	3.68 (0.95)	3.76 (0.79)	4.00 (0.87)
2	**2.22** Prolonged precariousness and ageing workforce **(CEPP)**	88.1	3.78 (0.98)	3.44 † (1.10)	3.59 † (0.93)	4.27 † (0.77)
3	**2.17** Introduction of unsafe / unhealthy work equipment, materials and goods **(OCMI)**	92.4	3.68 (0.96)	3.88 (0.81)	3.43 (0.97)	3.90 (1.02)
4	**2.20** OSH management in crowdsourcing, internships, zero hours contracts **(CEPP)**	79.1	3.64 (1.20)	3.35 (1.22)	3.83 (1.07)	3.62 (1.36)
5	**2.15** Restructuring, practical interventions to reduce OSH risks and support wellbeing **(ERP)**	84.1	3.62 (0.96)	3.38 (0.96)	3.58 (0.76)	3.86 (1.15)
3 – NEW TECHNOLOGIES						
1	**3.32** NOAA, standardised sampling and measurement methods **(ENM)**	96.6	4.00 (0.92)	3.63 (1.26)	4.00 (0.80)	4.27 (0.63)

2	**3.33** NOAA, regulations, guidelines and good practices **(ENM)**	91.2	3.90 (1.08)	3.57 (1.51)	4.05 (0.92)	3.96 (0.90)
3	**3.34** NOAA risk assessment: toxicological evaluation and bio-monitoring programs **(ENM)**	89.7	3.81 (1.02)	3.47 (1.46)	3.71 (0.96)	4.14 (0.56)
4	**3.36** NOAA, physical and chemical properties, research data and knowledge transfer **(ENM)**	87.7	3.79 (1.16)	3.20 ‡ (1.37)	3.67 (1.20)	4.33 ‡ (0.66)
5	**3.41** Smart PPE and adaptive/wearable sensors, environment and workers' monitoring **(ICT)**	85.1	3.70 (1.10)	3.44 (1.20)	3.55 (1.09)	4.15 (0.93)
4 – CHEMICAL AND BIOLOGICAL AGENTS						
1	**4.64** Multiple chemical exposures and interactions between chemicals and other risks **(CA)**	84.7	3.63 (1.14)	3.47 (1.18)	3.61 (1.20)	3.79 (1.08)
2	**4.60** Sampling and detection devices for early detection of chemicals **(CA)**	84.5	3.62 (1.01)	3.63 (1.20)	3.57 (0.95)	3.68 (0.95)
2	**4.57** Measurement devices and methods for sampling and assessment of bio-aerosols **(BA)**	87.3	3.62 (1.16)	3.35 (1.37)	3.90 (0.91)	3.56 (1.20)
4	**4.61** Reliable, non-invasive biomarkers to measure occupational exposure to chemicals **(CA)**	83.3	3.56 (1.08)	3.53 (1.13)	3.62 (1.02)	3.50 (1.15)
5	**4.66** CMRs and sensitising substances, Exposure modelling, Job-Exposure Matrix (**CA)**	83.0	3.51 (1.03)	3.36 (1.08)	3.50 (1.10)	3.65 (0.93)
MISCELLANEOUS						
1	**5.69** Translation of OSH research evidence into practical tools	86.1	3.82 (1.17)	3.63 (1.21)	3.90 (1.21)	3.87 (1.10)
2	**5.72** OSH implementation in micro, Small and Medium Enterprises (SMEs)	85.1	3.61 (1.17)	3.56 (1.20)	3.75 (0.97)	3.48 (1.40)
3	**5.75** Addressing OSH since the design stage in research on new technologies	75.0	3.33 (1.31)	2.94 (1.39)	3.66 (1.08)	3.16 (1.50)
4	**5.68** Tools and methods to support European companies' prevention needs	73.1	3.21 (1.25)	2.88 (1.26)	3.36 (1.25)	3.26 (1.25)
5	**5.71** Health inequalities among employees, workplaces, regions, sectors of employment	64.4	2.85 (1.11)	3.20 (1.01)	2.62 (1.20)	2.89 (1.02)

*3-5 = Moderately to Extremely important

† 0.009; SE>NE; SE>CE

‡ 0.015; SE>NE

DISCUSSION

The high level of participation in both rounds, with a high number of relevant research proposals submitted in the first, confirms the interest of the research community in being directly involved in the definition of research agendas and planning activities.

As regards the results, it is useful to note that 14 out of the 16 RTs coming from the first round of Delphi questionnaire obtained a MV between 3.14 and 3.90, showing a positive evaluation in terms of importance. In particular, the first 12 RTs were rated ≥ 3 by at least 80% of the sample.

Ageing of the workforce and return to work looks to be the core issue in the area of Demographic change, underlining the importance of answering the needs of prolonging working life in a healthy and productive way. On the other hand, topics still included in the area of Demographic change, which had a consolidated and relevant space within recent OSH agendas, such as vulnerable workers in general, migrant workers and gender issues seem to attract a lower interest in terms of OSH research.

In the area of Technological Innovation, the most relevant topic is that related to nanotechnologies. Nevertheless, the analysis by geographical distribution shows a specific relationship: in fact, this topic has the highest MV in Southern Europe, while its importance is significantly lower in the other geographical areas.

It is interesting to note that in the macro-area related to Technological innovation, *Emerging technological devices* appears, for the first time with this study, as an autonomous OSH research topic. As a matter of fact, the general topic obtained a higher rating than the specific priorities traced under this heading. This might be due to the perception that this kind of devices can have relevant long-term impacts in terms of innovation and sustainable growth, while the specific research priorities actually identified are still linked to small and

very specific projects, only precursors to wider future developments. It must be also noted that the level of importance attributed to this topic overtakes that of two other topics showing a much steadier link between health and safety and technological innovation, such as *ICT* and *Green Jobs*.

The lower importance assigned to *ICT* as a discrete topic might be due to the inclusion of the risks related to ICT as such into some other topics, like work organization, job content and ageing. On the other hand, green jobs still look not to have a full relevance within OSH issues. In fact, the priorities included in this topic highlight the need to develop a better knowledge and to define the effective relevance of the risks for workers' health and safety related to these technologies.

Enterprises' reorganisation processes and *OSH consequences of markets integration* are the two RTs that received the lowest rating among those included in the macro-area of Globalization. For the first, this might be due to the specific focus of research on actions to improve risk management and reduce risk exposure during these processes, rather than studying the impact of exposures, whose effects are already well known. For the second, notwithstanding the low MV obtained by the RT, the two RPs included received a much higher evaluation: the reason for this might be due to an unclear wording of the RT, while the more detailed definition of the priorities supported a better comprehension of the related OSH issues.

Among the RTs with the lowest rating, *Women at work* and *Electromagnetic fields* are also included. The low ranking of *Women at work* is in line with previous findings, which highlighted a relevant attention to the issue in terms of OSH implementation but not as an autonomous research topic.[29,34-35] However, the analysis by geographical distribution suggests some new food for thought, worthy of further study. Unlike other regions,

Southern Europe ranked both the RT and the related RPs amongst the highest in order of importance.

As regards *Electromagnetic Fields*, there is a clear contrast with previous studies. In fact, in the studies carried out by EU-OSHA to identify OSH research priorities, there was a strong emphasis on the need to explore the effects of the new applications of this technology.[4, 7] On the contrary, the present study shows a significant reduction in interest for this issue, with a MV lower than 3 in all the geographical regions and even lower than 2 in Northern Europe.

Among the 77 RPs included in the second round of the Delphi survey, 65 were rated with a MV higher than 3 (moderately important), recognizing a medium-high level of importance to the RP. This level of importance was assigned by at least 80% of the respondents in 44 RPs.

Some very new issues appeared amongst the top priorities. Particular importance has been attached to OSH management in new forms of employment (e.g. crowdsourcing, internships, zero hours contracts); OSH impacts of innovation and new ways of working (i.e. tele-work, e-work, boundary less work); health and safety in human-computer interaction; and, the introduction of unsafe and unhealthy work equipment following the reduction of barriers to the free movement of goods.

Finally, high importance was attributed to two transversal priorities, related to the translation of research results into practical and effective tools, and to the support for OSH implementation in micro, Small and Medium Enterprises (SMEs).

Strengths and limitations

The methodological approach used in the present study, develops previous experiences in an innovative way, by defining a path of full involvement of the research community in each

step of the priority setting process, from the identification of priorities to the assessment of their relevance and their ranking by level of importance.

The involvement of a European network of OSH research institutions has ensured not only a good representation of competencies and resources available across the network member institutes, but also a wide geographical coverage that made it possible to analyse the different level of perception and awareness of the several issues in different European regions.

On the other hand, the attitude of researchers to promote their own research activities as priorities represents a limitation of the study, particularly for the development of future research agendas, which goes beyond the boundaries of sectoral research and needs to be highly interdisciplinary to meet the objectives of innovative and sustainable growth set by the European research strategy.

These limitations have been mitigated, at least partially, by the identification of well-defined fields of interest through the reference to the four macro-areas of the EU-OSHA report.[7] In addition, the decision to invite the overall sample to assess the level of importance of the entire set of priorities, and not only of those included in their macro-area of expertise, allowed reduction of the importance of the single respondent's evaluations and consequently decreased the impact of such a bias.

Comparison with previous studies

This study ratifies the central role of some RTs whose relevance was already widely acknowledged by the literature. On the other hand, topics related to gender issues and electromagnetic fields, although still receiving high attention at policy level, show a lower demand for research.

In previous studies, gender issues were included in different areas of interest, both autonomously and related to exposure to particular risks (i.e. endocrine disruptors). In the present study, instead, gender issues obtained lower MV than other topics related to vulnerable workers, which made them slip out of the top five priorities in the macro area (see Supplementary Table for effective ranking of the topic and related priorities).

As regards electromagnetic fields, acknowledging that this topic has had a great relevance in the past both at political level and within the research community, they obtained the lowest MV (2.59).

Differently from previous studies, including the 2013 EU-OSHA report, the present one showed the absence of any reference to the themes of violence and harassment at work. Even if these issues are still relevant or becoming important in some countries in the world, it must be acknowledged that they have never been mentioned in the present study, not even among the over 350 research proposals collected at the end of the first round.

The study identifies some innovative RTs that are not reflected in previous studies, such as *Emerging Technological Devices* and *OSH consequences of markets integration*. Some new elements are also highlighted among RPs, such as new forms of work delivery (e.g. crowdsourcing, e-work, zero-hours contracts), which were only hinted in the 2013 EU-OSHA study.

Conclusions

This study allowed the identification and assessment of the relevance of a well-organized and fine-tuned set of RPs suitable for drawing up a proper agenda for further development of OSH research. This has been achieved through a process entirely shared with a large, geographically representative and qualified panel of European OSH researchers.

Therefore, it offers an effective representation of the OSH research community views on the needs for future research developments, able to contributing to the achievement of the innovation and sustainable growth objectives set by the European strategies.

Those priorities receiving a positive evaluation with a high level of consensus may represent the backbone of a reliable set of OSH research issues in the settlement of the next European Research Agendas.

Figure 1 – The modified Delphi process adopted in the study.

Competing Interests

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

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Data sharing

All available data have been published within the paper and the annex.

Contributorship statement

SI promoted the project and the work. DG, BMR, and SI each made substantial contributions to the conception and design of the study protocol. DG, BMR, MM, PE, MH and PP contributed to the collection and elaboration of data. BRM and GB designed and performed the data analysis. BMR, MM and AV wrote the manuscript. DG, PE, MH, PP and SI provided critical inputs regarding the discussion and conclusions of the manuscript. DG and SI revised the final version of the manuscript. SI approved the final version of the manuscript to be published.

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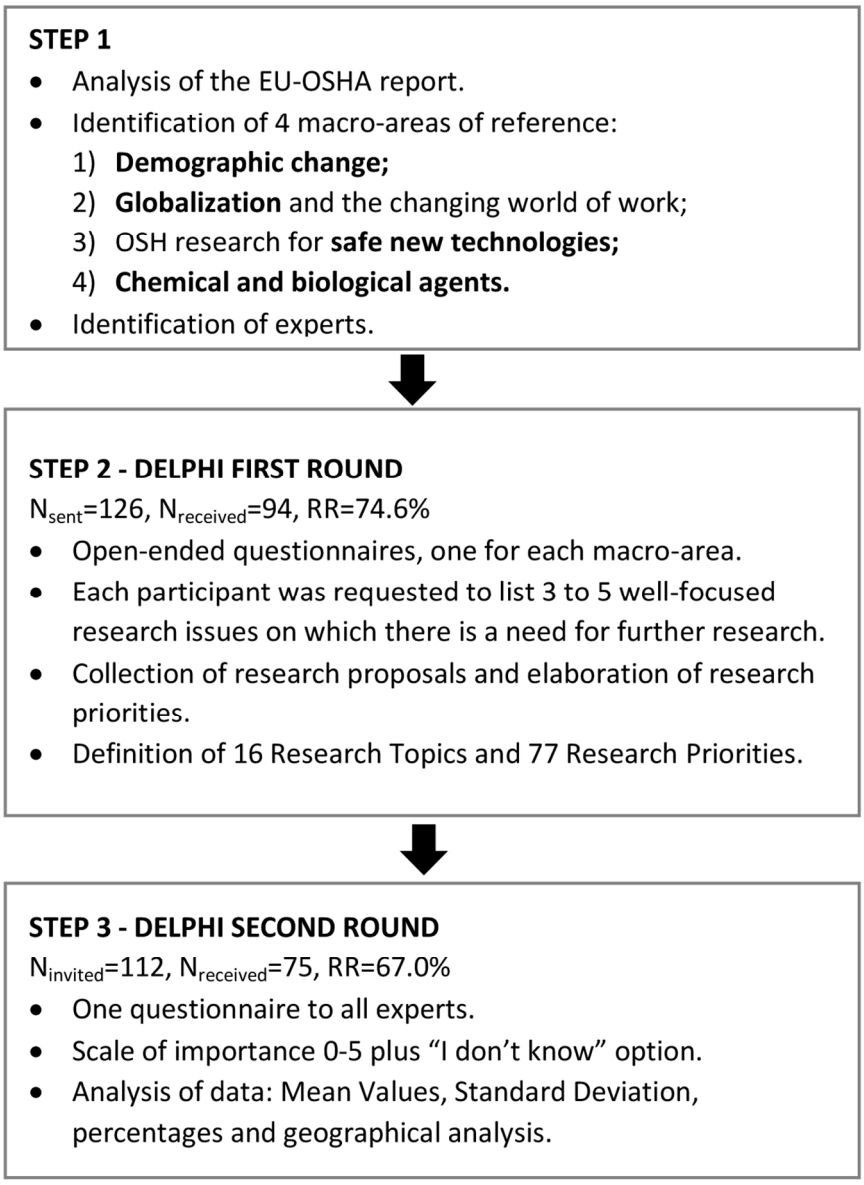

Figure 1 – The modified Delphi process adopted in the study.

102x139mm (300 x 300 DPI)

DELPHI QUESTIONNAIRE - First Round

We suggest to save the attached pdf file on your PC. You will be able to modify your inputs as necessary and save them not to lose your progresses. When you have filled out the questionnaire, please return the file as an attachment to: futures-perosh@inail.it

NAME _____ SURNAME _____

ORGANIZATION _____ COUNTRY _____

DEMOGRAPHIC CHANGE - Sustainable work for healthier and longer working lives

In the light of the demographic changes in the European context which are leading to the ageing of the workforce, to a growing involvement of women in sectors and jobs traditionally performed by men as well as to the increase of migrant workers, what do you think are the major issues that OSH research is required to address in order to support the provision of an even more appropriate protection of workers' health as well as the improvement of working conditions?

(Please, list a minimum of 3 and a maximum of 5 research issues written as short but self-explicative title of a research project, max 300 characters).

1. _____

2. _____

3. _____

4. _____

5. _____

Comments *(Please use this box if you wish to provide further information to better define any of the research issues outlined above and/or highlight its relevance)*

DELPHI QUESTIONNAIRE - First Round

We suggest to save the attached pdf file on your PC. You will be able to modify your inputs as necessary and save them not to lose your progresses. When you have filled out the questionnaire, please return the file as an attachment to: futures-perosh@inail.it

NAME _____ SURNAME _____

ORGANIZATION _____ COUNTRY _____

GLOBALIZATION AND THE CHANGING WORLD OF WORK - OSH research contribution to sustainable and inclusive growth

Economic changes brought in the European context by globalization, are leading to the spread of restructuring processes as well as to a wide turn to flexible and atypical contracts with a relevant impact on the organization of work and on the level and quality of OSH. What do you think are the major issues that OSH research should address in order to avoid negative impact on health and safety at the workplace?

(Please, list a minimum of 3 and a maximum of 5 research issues written as short but self-explicative title of a research project, max 300 characters.

1. _____

2. _____

3. _____

4. _____

5. _____

Comments *(Please use this box if you wish to provide further information to better define any of the research issues outlined above and/or highlight its relevance)*

DELPHI QUESTIONNAIRE - First Round

We suggest to save the attached pdf file on your PC. You will be able to modify your inputs as necessary and save them not to lose your progresses. When you have filled out the questionnaire, please return the file as an attachment to: futures-perosh@inail.it

NAME _____ SURNAME _____

ORGANIZATION _____ COUNTRY _____

OSH RESEARCH FOR SAFE NEW TECHNOLOGIES AS A PREREQUISITE FOR SUSTAINABLE GROWTH

New technologies and production processes are fast entering into the world of work introducing new risks or new ways of exposure to traditional risks. What do you think are the major issues that OSH research should address in order to protect the health and safety of those workers most concerned with the introduction of technological innovation?

(Please, list a minimum of 3 and a maximum of 5 research issues written as short but self-explicative title of a research project, max 300 characters).

1. _____

2. _____

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4. _____

5. _____

Comments *(Please use this box if you wish to provide further information to better define any of the research issues outlined above and/or highlight its relevance)*

DELPHI QUESTIONNAIRE - First Round

We suggest to save the attached pdf file on your PC. You will be able to modify your inputs as necessary and save them not to lose your progresses. When you have filled out the questionnaire, please return the file as an attachment to: futures-perosh@inail.it

NAME _____ SURNAME _____

ORGANIZATION _____ COUNTRY _____

RESEARCH INTO NEW OR INCREASING OCCUPATIONAL EXPOSURES TO CHEMICAL AND BIOLOGICAL AGENTS FOR THE BENEFIT OF A SMART AND SUSTAINABLE ECONOMY

Thinking about the current or foreseeable use of traditional materials/agents in innovative ways or the introduction of new materials in existing production processes, what do you think are the major issues that the OSH research should address in order to improve the protection of workers' health and safety, with special reference to the exposure to chemical and biological agents?

(Please, list a minimum of 3 and a maximum of 5 research issues written as short but self-explicative title of a research project, max 300 characters.

1. _____

2. _____

3. _____

4. _____

5. _____

Comments *(Please use this box if you wish to provide further information to better define any of the research issues outlined above and/or highlight its relevance)*

PERSONAL INFORMATION

Institute _____

Country _____

OLDER WORKERS **List of abbreviations in this page:** HRM = Human Resources Management MSDs = Musculo-Skeletal Disorders SMEs = Small and Medium Enterprises	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Extended working lives and prolonged workplace exposures to physical, chemical, biological and psychosocial hazards: development of techniques and models to collect lifelong exposure data and to assess the effects of such exposures on workers' H&S.	☐	☐	☐	☐	☐	☐	☐
Investigate the causes of early departure from work and the potential OSH measures (e.g. products, support, adaptation and incentives) to improve the work environment, and support, rehabilitate and retain ageing workers over a longer working life.	☐	☐	☐	☐	☐	☐	☐
Identify the potential impacts of work organisation and job design on older workers' H&S and the ways in which these can support individual older workers. Specific areas of interest include MSDs, stress, and interventions for SMEs.	☐	☐	☐	☐	☐	☐	☐

Investigate the role of HRM and improve their management practices on employee and organisational level outcomes, such as wellbeing/work ability, work engagement, resilience, retirement intentions, actual retirement transition and productivity.	☐	☐	☐	☐	☐	☐	☐

WOMEN AT WORK AND GENDER ASPECTS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Investigate and develop understanding of gender differences in occupational risks, including new and emerging risks.	☐	☐	☐	☐	☐	☐	☐
Investigate and reduce negative effects on women's safety behaviours, health and productivity of the interaction between work organisation and work environment, job insecurity, women's work-life balance and women's physiological conditions.	☐	☐	☐	☐	☐	☐	☐

MIGRANT WORKERS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	

Identify OSH issues for workers living away from their home country, for example low pay, poor working conditions, and poor H&S conditions.	☐	☐	☐	☐	☐	☐	☐
Understand and address the impact on OSH management of linguistic, cultural and knowledge diversity in multicultural workplaces: how to develop a sustainable and inclusive OSH system for multinational and multi-ethnic workforces.	☐	☐	☐	☐	☐	☐	☐

HEALTH INEQUALITIES AND WORK – VULNERABLE WORKERS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Investigate the extent of problems facing vulnerable workers using, for example, longitudinal studies, sector or group specific studies, comparative studies between countries, taking into account the impact of social determinants.	☐	☐	☐	☐	☐	☐	☐
Investigate the factors that could improve the situation for vulnerable workers using, for example, workplace intervention studies and individual solutions.	☐	☐	☐	☐	☐	☐	☐

DISABLED AND CHRONICALLY SICK WORKERS (WORK DISABILITY PREVENTION AND RETURN-TO-WORK RESEARCH)	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Working with disability (chronic degenerative diseases, oncological, neurodegenerative, dysmetabolic conditions): assess the impact of occupational risk factors on older workers with chronic diseases and define interventions to reduce time off work.	☐	☐	☐	☐	☐	☐	☐
Investigate ways and tools to prevent disability and to facilitate return to work in order to promote a longer working life, including adaptation of the workplace and work arrangements.	☐	☐	☐	☐	☐	☐	☐

ENTERPRISES' REORGANISATION PROCESSES *Restructuring, mergers and acquisitions, downsizing, closure, outsourcing, delocalisation and reshoring processes are included*	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Understand the effects of geographical relocation of enterprises (delocalisation and reshoring to and from low wage countries) on workers' H&S and local health services in the EU.	☐	☐	☐	☐	☐	☐	☐

Foster the emergence of a new approach to organisational change which allows enterprises managers to face, understand and overcome the negative impacts of restructuring on motivation, well-being and health of employees.	☐	☐	☐	☐	☐	☐	☐
Identify practical interventions to reduce OSH risks and to support employees' wellbeing during restructuring.	☐	☐	☐	☐	☐	☐	☐
Further improve knowledge on restructuring impact on risk factors (including psychosocial) for workers' H&S.	☐	☐	☐	☐	☐	☐	☐

OSH CONSEQUENCES OF MARKETS INTEGRATION BASED ON THE REDUCTION OF BARRIERS TO FREE MOVEMENT OF GOODS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Assess and reduce the risk of introducing unsafe and unhealthy work equipment, materials and goods into EU manufacturing processes and workplaces.	☐	☐	☐	☐	☐	☐	☐
OSH research contribution to the development of policies ensuring the trade of goods produced according to globally shared standards for the protection of workers' H&S.	☐	☐	☐	☐	☐	☐	☐

CHANGING EMPLOYMENT PATTERNS AND PRACTICES	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Precarious work and job insecurity: better understand and address effects on workers' H&S.	☐	☐	☐	☐	☐	☐	☐
OSH management in new forms of employment (crowdsourcing, internships, zero hours contracts).	☐	☐	☐	☐	☐	☐	☐
Impact of precarious jobs on work-life balance.	☐	☐	☐	☐	☐	☐	☐
Impact of prolonged precariousness on health conditions, wellbeing and quality of life of an ageing workforce.	☐	☐	☐	☐	☐	☐	☐

WORKING CONDITIONS, WORK ORGANISATION AND JOB CONTENT	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Identify best work organisation practices to deal with health effects of an increasingly sedentary workforce (e.g. obesity and Musculo-Skeletal Disorders - MSDs).	☐	☐	☐	☐	☐	☐	☐
Identify and address consequences on OSH of innovation and new ways of working, such as remote working practices (tele-work, e-work, boundary less work).	☐	☐	☐	☐	☐	☐	☐

Find a balance between the need of enhancing employees' control over their work practices and the increasing adoption of Enterprise Resource Planning (ERP) systems.	☐	☐	☐	☐	☐	☐	☐
Assessment of methods to improve management of psychosocial risks and promotion of psychosocial safety climate in ever increasingly competitive work environments.	☐	☐	☐	☐	☐	☐	☐
Assessment of work-related stress influence in companies (workers' health, productivity, etc.).	☐	☐	☐	☐	☐	☐	☐
Use and abuse of substances improving working performance and consequences on OSH.	☐	☐	☐	☐	☐	☐	☐
Impact of mobile work on workers' physical and psychosocial health.	☐	☐	☐	☐	☐	☐	☐
Management of OSH risks in multi-location work.	☐	☐	☐	☐	☐	☐	☐
Better understand and address effects of working-time flexibilisation (long working hours and shift work) on health, wellbeing and productivity of the working population (specific attention should to be paid to vulnerable workers).	☐	☐	☐	☐	☐	☐	☐

NANOMATERIALS **List of abbreviations in this page:** NOAA = Nano Objects, Agglomerates and Aggregates	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Develop standardised sampling and measurement methods to quantify and characterise exposure to NOAA.	☐	☐	☐	☐	☐	☐	☐

Develop regulations, guidelines and good practices for safely working with NOAA.	☐	☐	☐	☐	☐	☐	☐
Improve risk assessment for workers exposed to NOAA (toxicological evaluation, studies of effects on human and biological systems and development of bio-monitoring programs).	☐	☐	☐	☐	☐	☐	☐
Define Occupational Exposure Limits (OEL) for NOAA.	☐	☐	☐	☐	☐	☐	☐
Improve research data and knowledge transfer on physical and chemical properties of NOAA to define the best set of properties for the cause-effect relationship.	☐	☐	☐	☐	☐	☐	☐
Improve risk management tools for exposure to NOAA.	☐	☐	☐	☐	☐	☐	☐
Develop an information gathering approach for registration and toxicity testing for fibrous advanced materials.	☐	☐	☐	☐	☐	☐	☐

GREEN JOBS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Better understand OSH implications in the Green Economy (e.g. green biotechnologies and green construction, renewable energies, waste management and environmental bioremediation) through data collection and scientific analysis on risk exposure.	☐	☐	☐	☐	☐	☐	☐
Improve the identification and assessment of biological risks	☐	☐	☐	☐	☐	☐	☐

in the field of biofuel production (biomasses production, biogas plants, organic waste recovery), including the hazards related to the use of biotechnologies.							

INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Development of smart Personal Protective Equipment (PPE) and adaptive/wearable sensors for the monitoring of environmental conditions and workers' physiological parameters.	☐	☐	☐	☐	☐	☐	☐
Assessing the effects and impact of Information and Communication Technology (ICT) on workers' H&S, quality of working life and work-life balance.	☐	☐	☐	☐	☐	☐	☐
Legal and ethical issues of employee monitoring and collected data protection.	☐	☐	☐	☐	☐	☐	☐
Data Security and workers' safety in the Internet of Things (networks of physical objects that are embedded with the ability to exchange data, to interoperate with existing network infrastructure and that can be controlled remotely).	☐	☐	☐	☐	☐	☐	☐
H&S factors in the design and engineering of multimodal human-computer interaction and interaction devices.	☐	☐	☐	☐	☐	☐	☐

ELECTROMAGNETIC FIELDS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Investigation of interaction mechanisms of magnetic, electric and electromagnetic fields with biological systems.	☐	☐	☐	☐	☐	☐	☐
Electromagnetic fields in the workplace from advanced systems used in wireless communication and diagnostic technologies: human exposure and safe interaction with implantable therapeutic devices.	☐	☐	☐	☐	☐	☐	☐
Safety evaluation of long exposure to electromagnetic low level fields.	☐	☐	☐	☐	☐	☐	☐

EMERGING TECHNOLOGIES DEVICES	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Increasing use of 3D Printing and its implications on OSH.	☐	☐	☐	☐	☐	☐	☐
Ensure the full exploitation of opportunities and control of risks for workers' safety related to interaction between humans and robots.	☐	☐	☐	☐	☐	☐	☐
OSH implication of Automated Guided Vehicles (AGV) and	☐	☐	☐	☐	☐	☐	☐

Drones.							
OSH related to production, use and maintenance of battery powered devices, equipment and vehicles.	☐	☐	☐	☐	☐	☐	☐

BIOLOGICAL AGENTS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Investigate the contribution of microbial debris to the occupational exposure to airborne microorganism and the role of microorganisms in the development or aggravation of adverse health effects.	☐	☐	☐	☐	☐	☐	☐
Investigate occupational risks due to the use or production of Genetically Modified Organisms (GMOs) and Genetically Modified Microrganisms (GMMs).	☐	☐	☐	☐	☐	☐	☐
By means of Personal Protective Equipments (PPEs), new antibiotics and vaccines development, ensure proper protection of European workers' health from emerging pathogens introduced (or reintroduced) by globalisation and climate change.	☐	☐	☐	☐	☐	☐	☐
Identification of chemical markers and medical parameters for correlating the occupational exposure to biological agents.	☐	☐	☐	☐	☐	☐	☐
Development of appropriate measurement devices and	☐	☐	☐	☐	☐	☐	☐

standardised methods for workplace sampling and assessment of exposure to bio-aerosols.							
Analyses and hazard assessment of biological agents at workplaces with complex exposure situations.	☐	☐	☐	☐	☐	☐	☐
Investigate effects of bioremediation technologies and biodegradable substances used to replace chemicals on workers' health.	☐	☐	☐	☐	☐	☐	☐

CHEMICAL AGENTS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Improve sampling and detection devices in providing an early and reliable detection of chemicals.	☐	☐	☐	☐	☐	☐	☐
Increase the availability of reliable and non-invasive biomarkers for measuring occupational exposure to chemical substances and their effects.	☐	☐	☐	☐	☐	☐	☐
Develop the necessary "a priori" knowledge of chemicals safety to support the increase in the use of "safety by design" practices in the development of new materials or in the use of known materials in innovative ways.	☐	☐	☐	☐	☐	☐	☐
Scrutinising existing Occupational Exposure Limits (OEL) and their harmonisation with regulatory models (REACH and European Food Safety Authority - EFSA) in order to better	☐	☐	☐	☐	☐	☐	☐

protect workers' health.							
Deepen understanding of multiple chemical exposures and interactions between chemicals and other risk factors (e.g. shift work and physical agents).	☐	☐	☐	☐	☐	☐	☐
Deepen understanding of the relationship between individual (genetic) disposition and susceptibility against chemicals.	☐	☐	☐	☐	☐	☐	☐
Develop exposure modelling techniques for Carcinogenic, Mutagenic and Reprotoxic (CMR) and sensitising substances in order to construct a European Job-Exposure Matrix (JEM).	☐	☐	☐	☐	☐	☐	☐
Study on trends and significant changes in use of chemical and biological agents in the workplace (including information provided by Market Analysis).	☐	☐	☐	☐	☐	☐	☐

MISCELLANEOUS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Develop tools and methods to support European companies to better address their specific prevention needs and build programmes to monitor and “secure” employees’ health.	☐	☐	☐	☐	☐	☐	☐
From research to practice: translation of OSH research evidence into practical tools to be used at company level and identification of the best ways to reach workers.	☐	☐	☐	☐	☐	☐	☐

Development of a cross EU H&S qualification.	☐	☐	☐	☐	☐	☐	☐
Studies on polarisation of employees' occupational health resources in the labour market (between employees, workplaces, regions, sectors of employment) and prevention of processes leading to unequal distribution of health at various levels.	☐	☐	☐	☐	☐	☐	☐
OSH implementation in micro, Small and Medium Enterprises (SMEs): develop methods and tools to exploit available data to locate, identify, characterise and better regulate ever changing SMEs.	☐	☐	☐	☐	☐	☐	☐
Development of measurement techniques, assessment strategies and safety requirements for noise exposure in call centres.	☐	☐	☐	☐	☐	☐	☐
Non-audible noise: perception, influence, exposure limits, measurement techniques, assessment strategies, sources in new technologies and safety requirements.	☐	☐	☐	☐	☐	☐	☐
Develop knowledge, concepts, techniques and tools to foster a transdisciplinary approach to research on new technologies development, able to address OSH issues from the design stage.	☐	☐	☐	☐	☐	☐	☐
Ultrasound on bioeffects and safety: evaluating cell alterations at both cell membrane and genetic level at non-cavitation regime.	☐	☐	☐	☐	☐	☐	☐
Malodorous substances at the workplace: validating test systems determining unacceptable nuisance for	☐	☐	☐	☐	☐	☐	☐

Occupational Exposure Limits (OEL) setting purposes.							

LIST OF GENERAL TOPICS	**Not at all important**	**Little important**	**Slightly important**	**Moderately important**	**Very important**	**Extremely important**	**I don't know**
	0	**1**	**2**	**3**	**4**	**5**	
Older workers.	☐	☐	☐	☐	☐	☐	☐
Women at work and gender aspects.	☐	☐	☐	☐	☐	☐	☐
Migrant workers.	☐	☐	☐	☐	☐	☐	☐
Health inequalities and work – Vulnerable workers.	☐	☐	☐	☐	☐	☐	☐
Disabled and chronically sick workers (work disability prevention and return-to-work research).	☐	☐	☐	☐	☐	☐	☐
Enterprises' reorganisation processes (restructuring, mergers and acquisitions, downsizing, closure, outsourcing, delocalisation and reshoring).	☐	☐	☐	☐	☐	☐	☐
OSH consequences of markets integration based on the reduction of barriers to free movement of goods.	☐	☐	☐	☐	☐	☐	☐
Changing employment patterns and practices.	☐	☐	☐	☐	☐	☐	☐
Working conditions, work organisation and job content.	☐	☐	☐	☐	☐	☐	☐
Nanomaterials.	☐	☐	☐	☐	☐	☐	☐
Green jobs.	☐	☐	☐	☐	☐	☐	☐
Information and Communication Technology (ICT).	☐	☐	☐	☐	☐	☐	☐
Electromagnetic fields.	☐	☐	☐	☐	☐	☐	☐
Emerging technological devices.	☐	☐	☐	☐	☐	☐	☐

Biological agents.	☐	☐	☐	☐	☐	☐	☐
Chemical agents.	☐	☐	☐	☐	☐	☐	☐

Please, write your comments here.

SUPPLEMENTARY TABLE - List of Research Topics and Research Priorities. Descriptive statistics in total sample and by geographical distribution.

MACROAREA ***RESEARCH TOPICS*** Research Priorities	**Total sample (N=75)**					**Northern Europe (NE) (N=20)**		**Central Europe (CE) (N=31)**		**Southern Europe (SE) (N=24)**		**Sig.**	**POST HOC P<0.05**
	n	**Mean Value(SD)**	**0* (%)**	**1-2** (%)**	**3-5*** (%)**	**n**	**Mean Value(SD)**	**n**	**Mean Value(SD)**	**n**	**Mean Value(SD)**		
1 – DEMOGRAPHIC CHANGE													
1. OLDER WORKER	***73***	***3.90(0.82)***	***0.0***	***4.1***	***95.9***	***20***	***3.80(0.77)***	***30***	***3.83(0.87)***	***23***	***4.09(0.79)***	***ns***	
1.1 Extended working lives and prolonged workplace exposures to physical, chemical, biological and psychosocial hazards: development of techniques and models to collect lifelong exposure data and to assess the effects of such exposures on workers' H&S.	71	3.66(1.03)	0.0	14.1	85.9	20	3.40(1.10)	29	3.69(0.93)	22	3.86(1.08)	ns	
1.2 Investigate the causes of early departure from work and the potential OSH measures (e.g. products, support, adaptation and incentives) to improve the work environment, and support, rehabilitate and retain ageing workers over a longer working life.	69	3.51(1.02)	0.0	15.9	84.1	19	3.32(1.11)	28	3.64(0.83)	22	3.50(1.19)	ns	
1.3 Identify the potential impacts of work organisation and job design on older workers' H&S and the ways in which these can support individual older workers. Specific areas of interest include MSDs, stress, and interventions for SMEs.	70	3.70(1.01)	0.0	12.9	87.1	19	3.37(1.01)	29	3.76(0.87)	22	3.91(1.15)	ns	
1.4 Investigate the role of HRM and improve their management practices on employee and organisational level outcomes, such as wellbeing/work ability, work engagement, resilience, retirement intentions, actual retirement transition and productivity.	67	3.37(1.03)	0.0	16.4	83.6	18	3.17(1.10)	28	3.64(0.99)	21	3.19(0.98)	ns	
2. WOMEN AT WORK AND GENDER ASPECTS	***71***	***3.14(1.28)***	***4.2***	***23.9***	***71.9***	***19***	***2.74(1.45)***	***29***	***2.93(1.39)***	***23***	***3.74(0.69)***	***0.023***	***SE>NE SE>CE***
1.5 Investigate and develop understanding of gender differences in occupational risks, including new and emerging risks.	71	3.30(1.21)	4.2	16.9	78.9	19	3.16(0.96)	29	3.03(1.52)	23	3.74(0.81)	ns	
1.6 Investigate and reduce negative effects on women's safety behaviours, health and productivity of the interaction between work organisation and work environment, job insecurity, women's work-life balance and women's physiological conditions.	69	3.22(1.14)	1.4	23.2	75.4	18	2.72(1.13)	28	3.36(1.25)	23	3.44(0.90)	ns	
3. MIGRANT WORKERS	***71***	***3.45(1.27)***	***2.8***	***16.9***	***80.3***	***18***	***3.89(0.90)***	***30***	***3.03(1.50)***	***23***	***3.65(1.07)***	***ns***	
1.7 Identify OSH issues for workers living away from their home country, for example low pay, poor working conditions, and poor H&S conditions.	71	3.37(1.16)	1.4	21.1	77.5	20	3.40(0.88)	28	3.32(1.25)	23	3.39(1.31)	ns	
1.8 Understand and address the impact on OSH management of linguistic, cultural and knowledge diversity in multicultural workplaces: how to develop a sustainable and inclusive OSH	70	3.57(1.02)	1.4	12.9	85.7	19	3.63(0.83)	28	3.46(1.20)	23	3.65(0.94)	ns	

system for multinational and multi-ethnic workforces.													
4. HEALTH INEQUALITIES AND WORK – VULNERABLE WORKERS	***71***	***3.48(1.04)***	***0.0***	***16.9***	***83.1***	***20***	***3.55(0.95)***	***29***	***3.31(1.14)***	***22***	***3.64(1.00)***	***ns***	
1.9 Investigate the extent of problems facing vulnerable workers using, for example, longitudinal studies, sector or group specific studies, comparative studies between countries, taking into account the impact of social determinants.	68	3.35(1.10)	0.0	22.1	77.9	20	3.30(1.26)	26	3.31(1.05)	22	3.46(1.06)	ns	
1.10 Investigate the factors that could improve the situation for vulnerable workers using, for example, workplace intervention studies and individual solutions.	69	3.32(1.01)	0.0	18.8	81.2	20	3.15(0.99)	27	3.37(0.88)	22	3.41(1.18)	ns	
5. DISABLED AND CHRONICALLY SICK WORKERS (WORK DISABILITY PREVENTION AND RETURN-TO-WORK RESEARCH)	***73***	***3.66(0.96)***	***0.0***	***11.0***	***89.0***	***20***	***3.50(0.83)***	***30***	***3.67(0.99)***	***23***	***3.78(1.04)***	***ns***	
1.11 Working with disability (chronic degenerative diseases, oncological, neurodegenerative, dysmetabolic conditions): assess the impact of occupational risk factors on older workers with chronic diseases and define interventions to reduce time off work.	67	3.55(0.99)	0.0	16.4	83.6	18	3.39(0.92)	28	3.54(1.04)	21	3.71(1.01)	ns	
1.12 Investigate ways and tools to prevent disability and to facilitate return to work in order to promote a longer working life, including adaptation of the workplace and work arrangements.	68	3.88(0.92)	0.0	7.4	92.6	17	3.65(0.86)	29	3.83(0.95)	22	4.09(0.92)	ns	
2 – GLOBALIZATION AND THE CHANGING WORLD OF WORK													
6. ENTERPRISES' REORGANISATION PROCESSES (RESTRUCTURING, MERGERS AND ACQUISITIONS, DOWNSIZING, CLOSURE, OUTSOURCING, DELOCALISATION AND RESHORING)	***66***	***3.15(1.23)***	***1.5***	***25.8***	***72.7***	***17***	***2.82(1.19)***	***29***	***3.21(1.26)***	***20***	***3.35(1.23)***	***ns***	
2.13 Understand the effects of geographical relocation of enterprises (delocalisation and reshoring to and from low wage countries) on workers' H&S and local health services in the EU.	62	3.10(1.00)	0.0	27.4	72.6	14	2.93(0.83)	26	3.06(1.02)	22	3.32(1.09)	ns	
2.14 Foster the emergence of a new approach to organisational change which allows enterprises managers to face, understand and overcome the negative impacts of restructuring on motivation, well-being and health of employees.	61	3.48(1.09)	0.0	21.3	78.7	17	3.06(0.66)	25	3.52(1.12)	19	3.79(1.27)	0.046	SE>NE
2.15 Identify practical interventions to reduce OSH risks and to support employees' wellbeing during restructuring.	63	3.62(0.96)	0.0	15.9	84.1	16	3.38(0.96)	26	3.58(0.76)	21	3.86(1.15)	ns	
2.16 Further improve knowledge on restructuring impact on risk factors (including psychosocial) for workers' H&S.	62	3.44(1.07)	0.0	16.1	83.9	14	3.21(1.12)	27	3.56(0.89)	21	3.43(1.25)	ns	
7. OSH CONSEQUENCES OF MARKET INTEGRATION BASED ON THE REDUCTION OF BARRIERS TO FREE MOVEMENT OF GOODS	***62***	***2.85(1.14)***	***3.2***	***29.1***	***67.7***	***14***	***2.43(1.34)***	***27***	***2.81(1.08)***	***21***	***3.19(1.03)***	***ns***	
2.17 Assess and reduce the risk of introducing unsafe and unhealthy	66	3.68(0.96)	0.0	7.6	92.4	16	3.88(0.81)	30	3.43(0.97)	20	3.90(1.02)	ns	

work equipment, materials and goods into EU manufacturing processes and workplaces.													
2.18 OSH research contribution to the development of policies ensuring the trade of goods produced according to globally shared standards for the protection of workers' H&S.	61	3.43(1.12)	0.0	16.4	83.6	14	3.57(1.16)	29	3.35(1.08)	18	3.44(1.20)	ns	
8. CHANGING EMPLOYMENT PATTERNS AND PRACTICES	***69***	***3.65(1.04)***	***0.0***	***14.5***	***85.5***	***19***	***3.32(1.11)***	***30***	***3.77(0.94)***	***20***	***3.80(1.11)***	***ns***	
2.19 Precarious work and job insecurity: better understand and address effects on workers' H&S.	67	3.55(1.00)	0.0	14.9	85.1	17	3.24(0.97)	28	3.57(1.03)	22	3.77(0.97)	ns	
2.20 OSH management in new forms of employment (crowdsourcing, internships, zero hours contracts).	67	3.64(1.20)	0.0	20.9	79.1	17	3.35(1.22)	29	3.83(1.07)	21	3.62(1.36)	ns	
2.21 Impact of precarious jobs on work-life balance.	67	3.46(1.06)	0.0	19.4	80.6	18	3.17(1.04)	27	3.48(1.01)	22	3.68(1.13)	ns	
2.22 Impact of prolonged precariousness on health conditions, wellbeing and quality of life of an ageing workforce.	67	3.78(0.98)	0.0	11.9	88.1	18	3.44(1.10)	27	3.59(0.93)	22	4.27(0.77)	0.009	SE>NE SE>CE
9. WORKING CONDITIONS, WORK ORGANISATION AND JOB CONTENT	***72***	***3.81(1.03)***	***0.0***	***12.5***	***87.5***	***18***	***3.61(1.15)***	***31***	***3.94(1.00)***	***23***	***3.78(1.00)***	***ns***	
2.23 Identify best work organisation practices to deal with health effects of an increasingly sedentary workforce (e.g. obesity and Musculo-Skeletal Disorders - MSDs).	69	3.41(1.10)	0.0	18.8	81.2	19	3.11(1.24)	29	3.62(1.18)	21	3.38(0.81)	ns	
2.24 Identify and address consequences on OSH of innovation and new ways of working, such as remote working practices (tele-work, e-work, boundary less work).	68	3.62(1.07)	0.0	17.6	82.4	17	3.06(1.09)	30	3.90(0.92)	21	3.67(1.11)	0.037	CE>NE
2.25 Find a balance between the need of enhancing employees' control over their work practices and the increasing adoption of Enterprise Resource Planning (ERP) systems.	55	3.13(1.02)	0.0	27.3	72.7	13	2.85(0.80)	26	3.15(1.22)	16	3.31(0.79)	ns	
2.26 Assessment of methods to improve management of psychosocial risks and promotion of psychosocial safety climate in ever increasingly competitive work environments.	67	3.52(1.05)	0.0	16.4	83.6	16	3.38(1.03)	29	3.62(1.08)	22	3.50(1.06)	ns	
2.27 Assessment of work-related stress influence in companies (workers' health, productivity, etc.).	69	3.45(0.98)	0.0	15.9	84.1	18	3.22(0.81)	29	3.55(0.87)	22	3.50(1.23)	ns	
2.28 Use and abuse of substances improving working performance and consequences on OSH.	67	2.75(1.12)	0.0	41.8	58.2	17	2.18(0.88)	28	2.86(1.18)	22	3.05(1.09)	0.041	SE>NE
2.29 Impact of mobile work on workers' physical and psychosocial health.	67	3.25(1.09)	0.0	23.9	76.1	17	2.82(0.88)	29	3.52(1.06)	21	3.24(1.22)	ns	
2.30 Management of OSH risks in multi-location work.	66	3.29(1.09)	1.5	21.2	77.3	17	2.94(1.09)	29	3.38(1.15)	20	3.45(1.00)	ns	
2.31 Better understand and address effects of working-time flexibilisation (long working hours and shift work) on health, wellbeing and productivity of the working population (specific attention should to be paid to vulnerable workers).	70	3.81(0.86)	0.0	7.1	92.9	19	3.68(0.95)	29	3.76(0.79)	22	4.00(0.87)	ns	
3 – OSH RESEARCH FOR SAFE NEW TECHNOLOGIES													
10. NANOMATERIALS	***63***	***3.89(0.95)***	***0.0***	***11.1***	***88.9***	***15***	***3.53(1.30)***	***26***	***3.69(0.84)***	***22***	***4.36(0.58***	***0.015***	***SE>CE***
3.32 Develop standardised sampling and measurement methods to quantify and characterise exposure to NOAA.	58	4.00(0.92)	1.7	1.7	96.6	16	3.63(1.26)	20	4.05(0.80)	22	4.27(0.63)	ns	

3.33 Develop regulations, guidelines and good practices for safely working with NOAA.	57	3.90(1.08)	1.8	7.0	91.2	14	3.57(1.51)	21	4.00(0.92)	22	3.96(0.90)	ns	
3.34 Improve risk assessment for workers exposed to NOAA (toxicological evaluation, studies of effects on human and biological systems and development of bio-monitoring programs).	58	3.81(1.02)	1.7	8.6	89.7	15	3.47(1.46)	21	3.71(0.96)	22	4.14(0.56)	ns	
3.35 Define Occupational Exposure Limits (OEL) for NOAA.	59	3.63(1.20)	1.6	15.3	83.1	15	3.13(1.51)	22	3.55(1.26)	22	4.00(0.76)	ns	
3.36 Improve research data and knowledge transfer on physical and chemical properties of NOAA to define the best set of properties for the cause-effect relationship.	57	3.79(1.16)	1.8	10.5	87.7	15	3.20(1.37)	21	3.67(1.20)	21	4.33(0.66)	0.015	SE>NE
3.37 Improve risk management tools for exposure to NOAA.	59	3.70(1.10)	1.7	11.9	86.4	16	3.38(1.20)	21	3.48(1.17)	22	4.14(0.83)	0.030	SE>NE SE>CE
3.38 Develop an information gathering approach for registration and toxicity testing for fibrous advanced materials.	53	3.57(1.07)	1.9	13.2	84.9	14	3.43(1.40)	21	3.71(1.00)	18	3.44(0.86)	ns	
11. GREEN JOBS	***70***	***3.44(0.97)***	***0.0***	***12.9***	***87.1***	***18***	***3.33(1.09)***	***30***	***3.37(1.10)***	***22***	***3.64(0.66)***	***ns***	
3.39 Better understand OSH implications in the Green Economy (e.g. green biotechnologies and green construction, renewable energies, waste management and environmental bioremediation) through data collection and scientific analysis on risk exposure.	65	3.57(0.98)	0.0	9.2	90.8	18	3.44(0.78)	25	3.44(1.16)	22	3.82(0.91)	ns	
3.40 Improve the identification and assessment of biological risks in the field of biofuel production (biomasses production, biogas plants, organic waste recovery), including the hazards related to the use of biotechnologies.	59	3.51(1.02)	0.0	15.3	84.7	18	3.67(0.69)	22	3.18(1.26)	19	3.74(0.93)	ns	
12. INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)	***69***	***3.58(1.13)***	***1.4***	***14.5***	***84.1***	***17***	***3.12(1.36)***	***29***	***3.90(1.05)***	***23***	***3.52(0.95)***	***ns***	
3.41 Development of smart Personal Protective Equipment (PPE) and adaptive/wearable sensors for the monitoring of environmental conditions and workers' physiological parameters.	67	3.70(1.10)	0.0	14.9	85.1	18	3.44(1.20)	29	3.55(1.09)	20	4.15(0.93)	ns	
3.42 Assessing the effects and impact of Information and Communication Technology (ICT) on workers' H&S, quality of working life and work-life balance.	67	3.36(1.08)	0.0	22.4	77.6	18	3.11(1.08)	28	3.79(1.07)	21	3.00(0.95)	0.013	CE>SE
3.43 Legal and ethical issues of employee monitoring and collected data protection.	66	3.38(1.16)	1.5	15.2	83.3	18	3.28(1.13)	28	3.54(1.20)	20	3.30(1.17)	ns	
3.44 Data Security and workers' safety in the Internet of Things (networks of physical objects that are embedded with the ability to exchange data, to interoperate with existing network infrastructure and that can be controlled remotely).	64	3.39(1.35)	0.0	28.1	71.9	16	2.94(1.65)	28	3.75(1.24)	20	3.25(1.16)	ns	
3.45 H&S factors in the design and engineering of multimodal human-computer interaction and interaction devices.	64	3.55(1.02)	0.0	17.2	82.8	16	3.13(1.03)	28	3.75(0.97)	20	3.60(1.05)	ns	
13. ELECTROMAGNETIC FIELDS	***61***	***2.59(1.26)***	***6.5***	***41.0***	***52.5***	***17***	***1.82(1.24)***	***26***	***2.92(1.20)***	***18***	***2.83(1.10)***	***0.013***	***NE<CE***

													NE<SE
3.46 Investigation of interaction mechanisms of magnetic, electric and electromagnetic fields with biological systems.	57	2.97(1.31)	5.3	28.1	66.6	14	2.14(1.41)	24	3.17(1.09)	19	3.32(1.29)	0.023	NE<SE
3.47 Electromagnetic fields in the workplace from advanced systems used in wireless communication and diagnostic technologies: human exposure and safe interaction with implantable therapeutic devices.	58	2.97(1.32)	3.4	29.3	67.3	14	2.14(1.29)	24	3.29(1.23)	20	3.15(1.27)	0.030	NE<CE
3.48 Safety evaluation of long exposure to electromagnetic low level fields.	56	2.86(1.47)	8.9	32.2	58.9	12	2.00(1.35)	25	2.88(1.42)	19	3.37(1.42)	0.035	NE<SE
14. EMERGING TECHNOLOGICAL DEVICES	***71***	***3.87(0.96)***	***0.0***	***7.0***	***93.0***	***17***	***3.71(0.85)***	***31***	***4.03(0.88)***	***23***	***3.78(1.13)***	***ns***	
3.49 Increasing use of 3D Printing and its implications on OSH.	63	3.29(1.10)	0.0	22.2	77.8	16	3.25(0.93)	28	3.36(1.25)	19	3.21(1.03)	ns	
3.50 Ensure the full exploitation of opportunities and control of risks for workers' safety related to interaction between humans and robots.	64	3.48(1.20)	3.1	12.5	84.4	17	3.18(0.95)	28	3.86(1.01)	19	3.21(1.51)	ns	
3.51 OSH implication of Automated Guided Vehicles (AGV) and Drones.	62	3.29(1.22)	1.6	19.4	79.0	17	3.06(1.09)	27	3.37(1.25)	18	3.39(1.34)	ns	
3.52 OSH related to production, use and maintenance of battery powered devices, equipment and vehicles.	63	3.06(1.19)	3.2	25.4	71.4	16	2.81(1.05)	28	3.39(1.13)	19	2.79(1.32)	ns	
4 – CHEMICAL AND BIOLOGICAL AGENTS													
15. BIOLOGICAL AGENTS	***64***	***3.58(0.97)***	***0.0***	***15.6***	***84.4***	***17***	***3.29(1.21)***	***26***	***3.62(0.98)***	***21***	***3.76(0.70)***	***ns***	
4.53 Investigate the contribution of microbial debris to the occupational exposure to airborne microorganism and the role of microorganisms in the development or aggravation of adverse health effects.	46	3.20(1.19)	2.2	15.2	82.6	13	3.31(1.25)	19	3.26(1.05)	14	3.00(1.36)	ns	
4.54 Investigate occupational risks due to the use or production of Genetically Modified Organisms (GMOs) and Genetically Modified Microrganisms (GMMs).	55	2.84(1.37)	5.5	32.7	61.8	16	2.44(1.32)	21	3.14(1.35)	18	2.83(1.43)	ns	
4.55 By means of Personal Protective Equipments (PPEs), new antibiotics and vaccines development, ensure proper protection of European workers' health from emerging pathogens introduced (or reintroduced) by globalisation and climate change.	55	3.42(1.21)	0.0	20.0	80.0	15	3.00(1.25)	21	3.43(1.25)	19	3.74(1.10)	ns	
4.56 Identification of chemical markers and medical parameters for correlating the occupational exposure to biological agents.	53	3.32(1.25)	0.0	28.3	71.7	15	3.13(1.30)	21	3.33(1.16)	17	3.41(1.37)	ns	
4.57 Development of appropriate measurement devices and standardised methods for workplace sampling and assessment of exposure to bio-aerosols.	55	3.62(1.16)	0.0	12.7	87.3	17	3.35(1.37)	20	3.90(0.91)	18	3.56(1.20)	ns	
4.58 Analyses and hazard assessment of biological agents at workplaces with complex exposure situations.	58	3.43(1.03)	0.0	19.0	81.0	16	3.56(1.21)	24	3.46(0.93)	18	3.28(1.02)	ns	
4.59 Investigate effects of bioremediation technologies and biodegradable substances used to replace chemicals on workers' health.	54	3.35(0.97)	0.0	18.5	81.5	16	3.13(1.09)	21	3.33(0.97)	17	3.53(0.87)	ns	

16. CHEMICAL AGENTS	***64***	***3.83(0.94)***	***0.0***	***10.9***	***89.1***	***17***	***3.59(1.12)***	***26***	***3.96(0.77)***	***21***	***3.86(0.96)***	***ns***
4.60 Improve sampling and detection devices in providing an early and reliable detection of chemicals.	58	3.62(1.01)	0.0	15.5	84.5	16	3.63(1.20)	23	3.57(0.95)	19	3.68(0.95)	ns
4.61 Increase the availability of reliable and non-invasive biomarkers for measuring occupational exposure to chemical substances and their effects.	54	3.56(1.08)	0.0	16.7	83.3	15	3.53(1.13)	21	3.62(1.02)	18	3.50(1.15)	ns
4.62 Develop the necessary "a priori" knowledge of chemicals safety to support the increase in the use of "safety by design" practices in the development of new materials or in the use of known materials in innovative ways.	55	3.47(1.15)	0.0	23.6	76.4	15	3.00(1.41)	21	3.71(0.96)	19	3.58(1.07)	ns
4.63 Scrutinising existing Occupational Exposure Limits (OEL) and their harmonisation with regulatory models (REACH and European Food Safety Authority -EFSA) in order to better protect workers' health.	52	3.44(1.18)	0.0	23.1	76.9	14	3.50(0.94)	21	3.24(1.41)	17	3.65(1.06)	ns
4.64 Deepen understanding of multiple chemical exposures and interactions between chemicals and other risk factors (e.g. shift work and physical agents).	59	3.63(1.14)	1.7	13.6	84.7	17	3.47(1.18)	23	3.61(1.20)	19	3.79(1.08)	ns
4.65 Deepen understanding of the relationship between individual (genetic) disposition and susceptibility against chemicals.	56	2.89(1.29)	1.8	35.7	62.5	16	2.81(1.33)	22	2.59(1.26)	18	3.33(1.24)	ns
4.66 Develop exposure modelling techniques for Carcinogenic, Mutagenic and Reprotoxic (CMR) and sensitising substances in order to construct a European Job-Exposure Matrix (JEM).	53	3.51(1.03)	0.0	17.0	83.0	14	3.36(1.08)	22	3.59(1.10)	17	3.65(0.93)	ns
4.67 Study on trends and significant changes in use of chemical and biological agents in the workplace (including information provided by Market Analysis).	56	3.23(1.04)	0.0	26.8	73.2	15	3.33(0.98)	22	3.23(0.92)	19	3.16(1.26)	ns
MISCELLANEOUS												
5.68 Develop tools and methods to support European companies to better address their specific prevention needs and build programmes to monitor and “secure” employees’ health.	67	3.21(1.25)	3.0	23.9	73.1	16	2.88(1.26)	28	3.36(1.25)	23	3.26(1.25)	ns
5.69 From research to practice: translation of OSH research evidence into practical tools to be used at company level and identification of the best ways to reach workers.	72	3.82(1.17)	1.4	12.5	86.1	19	3.63(1.21)	30	3.96(1.21)	23	3.87(1.10)	ns
5.70 Development of a cross EU H&S qualification.	66	2.55(1.26)	7.6	34.8	57.6	17	2.29(1.05)	29	2.52(1.53)	20	2.80(0.95)	ns
5.71 Studies on polarisation of employees' occupational health resources in the labour market (between employees, workplaces, regions, sectors of employment) and prevention of processes leading to unequal distribution of health at various levels.	59	2.85(1.11)	1.7	33.9	64.4	15	3.20(1.01)	26	2.62(1.20)	18	2.89(1.02)	ns
5.72 OSH implementation in micro, Small and Medium Enterprises (SMEs): develop methods and tools to exploit available data to locate, identify, characterise and better regulate ever changing SMEs.	67	3.61(1.17)	1.5	13.4	85.1	18	3.56(1.20)	28	3.75(0.97)	21	3.48(1.40)	ns

5.73 Development of measurement techniques, assessment strategies and safety requirements for noise exposure in call centres.	62	2.36(1.22)	3.2	46.8	50.0	15	1.87(0.92)	28	2.54(1.29)	19	2.47(1.26)	ns	
5.74 Non-audible noise: perception, influence, exposure limits, measurement techniques, assessment strategies, sources in new technologies and safety requirements.	54	2.76(1.26)	5.6	33.3	61.1	14	1.79(1.05)	26	3.31(0.93)	14	2.71(1.44)	0.001	NE<CE
5.75 Develop knowledge, concepts, techniques and tools to foster a transdisciplinary approach to research on new technologies development, able to address OSH issues from the design stage.	64	3.33(1.31)	4.7	20.3	75.0	16	2.94(1.39)	29	3.66(1.08)	19	3.16(1.50)	ns	
5.76 Ultrasound on bioeffects and safety: evaluating cell alterations at both cell membrane and genetic level at non-cavitation regime.	41	2.15(1.37)	12.2	48.8	39.0	12	1.83(1.40)	17	1.94(1.35)	12	2.75(1.29)	ns	
5.77 Malodorous substances at the workplace: validating test systems determining unacceptable nuisance for Occupational Exposure Limits (OEL) setting purposes.	54	2.07(1.21)	7.4	55.6	37.0	13	1.39(0.96)	24	2.46(1.10)	17	2.06(1.35)	0.037	NE<CE