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REVIEW

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Risk assessment and management of chemical hazards for pregnant workers: a qualitative review of guidance from EU member states

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Abstract

Background Exposure to workplace chemicals can pose serious risks to reproductive health. The European Union's Pregnant Workers Directive requires risk assessments but lacks clear guidelines for assessing chemical reproductive hazards in workplaces.

Aims This study aims to review how EU member states implement the Pregnant Workers Directive by analysing national guidance documents and relevant literature.

Methods A qualitative review was conducted, combining a systematic literature search with outreach to EU national experts to gather relevant guidance documents. Thematic synthesis identified guiding principles for implementing maternity protection for chemical exposures.

Results Two main themes were identified: the need for a broad perspective and for certainty in risk assessment. The broad perspective stresses the importance of considering all reproductive hazards, not limited to those listed in the EU Directive and inclusion of male workers and the preconception period, and the potential adverse socio-economic consequences of applied protective measures. The need for certainty highlights the challenges in reliable risk assessments, due to lack of knowledge about chemicals' hazardous properties, dose-response relationships and the level of worker exposure. These themes reveal the complexity of implementing effective maternity protection and the need for improved guidelines across the EU.

Conclusions This study calls for a unified approach to reproductive health protection, extending beyond pregnancy to include also preconception and paternal exposures. The findings highlight the need to support practitioners in the risk assess process at workplaces in the EU by providing a framework for the assessment of reproductive hazards and determining protective measures.

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Introduction

That parental occupational exposure to chemicals may affect reproductive health is well-documented. Examples include increased time to pregnancy, impaired foetal growth, miscarriage, congenital malformations and preterm birth [1]. Additionally, health later in life is affected as well, as prenatal and early development environmental exposures affect the etiology of and susceptibility to many noncommunicable diseases such as asthma [2, 3]. The working environment remains an important source of hazardous exposures. However, the proportion of reproductive health problems attributable to occupational exposures and the share of the workforce exposed to reproductive toxicants remains unknown and further clarification is necessary [4, 5].

To prevent adverse effects on pregnancy and the unborn child due to occupational exposures, the European Union (EU) has specific legislation through the Pregnant Workers Directive (92/85/EEC) [6]. The directive outlines minimum legal entitlements and protection for pregnant workers in the EU. EU member states must incorporate these minimal requirements in their national legislation but are free to adopt stricter rules. Specifically for chemical exposures, the directive contains two annexes: annex I, which lists criteria for chemicals for which risks should be assessed, and annex II, listing a (limited) number of agents and working conditions to which pregnant worker may not be exposed. An important basis for handling of chemicals in this respect is the classification of chemicals as reproductive toxicants under EC regulation. First, the classification, labelling and packaging (CLP) directive [7] classifies substances in category 1 A ("known") when reproductive toxicity in humans is well-established, category 1B ("presumed") is assigned if human data are limited but strong animal evidence exists. Category 2 ("suspected") is used when there is some evidence suggesting reproductive toxicity, but it is insufficient for Category 1. Second, the carcinogens and mutagens directive (CMRD) classifies reprotoxic agents as either having a threshold, where below this level exposure is safe, or as non-threshold, indicating that no safe level of exposure is identified [8].

In a follow-up communication the European Commission provided only minimal further guidance [9]. However, this legislative framework does not specify *how* risks to pregnancy should be assessed for the substances in annex I. Although the EU provides general guidance on occupational risk assessment, this does not specifically address the risks of pregnant workers [10]. The inherent difficulties in applying the present legislative framework might therefore lead to systematic withdrawal of pregnant workers from work with a perceived risk (instead of adapting their working conditions) and hence adverse socioeconomic effects and increased gender-based division in the workforce, resulting in negative effects on employment and women's careers [11]. In practice, the lack of specific guidance in this "open-ended" legal framework might also create barriers in the protection of pregnant workers. For example, a recent inspection campaign by the Belgian Federal Health and Safety Authority revealed that approximately half of the inspected companies in the domestic cleaning sector did not comply with the legal obligation to conduct pregnant worker protection risk assessments [12].

It is a question whether the implementation of the EU directive by the member states were accompanied by more practical advice on how to perform risk assessment for pregnant workers. This study aimed to analyse existing guidelines in the European Union and its member states on chemical risk assessment and management during pregnancy. Through outreach to national experts and searches of the peer-reviewed literature, we gathered guidance documents from EU member states and extracted instructions on how to assess and manage chemical hazards for pregnant workers. We then reviewed these documents using a qualitative analysis. The resulting overview of their content and key principles may help inform the development of future guidelines.

Methods

Data collection

This qualitative review combined a search for peer-reviewed literature with an outreach for national guidance documents, developed by the first author (T.C.) and reviewed by the last author (S.R.). A broad search for peer-reviewed papers was performed by searching for all reviews, editorials, guidelines or similar documents on pregnancy and occupational exposures. The most recent search was carried out on the 27/07/2024 in MEDLINE (via PubMed interface) and Embase (via embase.com interface), with no limit on date back in time. Search terms were identified using MeSH and Emtree thesauruses for pregnancy, reproductive health, and occupational exposures. The search string was manually adapted for each database and can be found in Table 1.

Additionally, owing to the lack of identified peer-reviewed literature on this subject, a search for national guidance documents was performed. This was accomplished by outreach to all EU-OSHA focal points on 16/09/2023 to request any pertinent guidelines on evaluating chemical risks in the workplace for pregnant worker protection, available in their country. If no response was received within 4 weeks, a reminder was sent. A similar strategy was applied to the International Commission on Occupational Health (ICOH) national secretaries of EU member states, with a first outreach on 11/11/2023 and a subsequent reminder sent after four weeks.

Table 1 Search strings per database

Database	Search strategy
PUBMED	((Pregnancy[MeSH Terms] OR pregnant women[MeSH Terms] OR reproductive health[MeSH Terms]) AND (occupational exposure[MeSH Terms])) AND ("Review" [Publication Type] OR "Guideline" [Publication Type] OR "Editorial" [Publication Type] OR "Congresses as Topic"[Mesh])
EMBASE	('pregnancy'/exp OR 'pregnant woman'/exp OR 'reproductive health'/exp) AND ('occupational exposure'/exp OR 'chemical exposure'/exp) AND ('review'/exp OR 'practice guideline'/exp OR 'editorial'/exp OR 'consensus'/exp)

Inclusion & exclusion criteria

Documents were included when they provided guidance on how to manage chemical risks in the workplace, going beyond what is included in the pregnant workers directive.

Because of EU's legislative framework within which maternity protection is enacted, only documents originating from within the European Union were considered for the analysis. In addition, only documents issued by national occupational health authorities or relevant professional organisations were considered for inclusion, to ensure a certain level of quality.

Data screening

The peer-reviewed literature was screened using a tiered approach, sequentially assessing titles, abstracts, and full texts. The national guidance documents were all screened at the full-text level.

Quality appraisal using AGREE II [13] was not possible due to the heterogeneity of documents.

This instrument assesses the methodological rigour and transparency in which a practice guideline is developed. Most analysed documents were not positioned as evidence-based guidelines, as the majority were practical tools for the implementation of the national legislation, thus not matching the scope of AGREE II.

Data extraction

Documents that were not in English were translated using Google Translate and were subjected to inductive coding by the first author. The software program NVivo 14 [14] facilitated this analytical process.

Evidence synthesis

Data analysis was conducted using a thematic synthesis approach as described in the methodology outlined by Thomas et al. [15]. Thematic synthesis follows an iterative, three-step process:

(i) Line-by-line coding of the documents to extract concepts, initiating synthesis (e.g., mentions of epidemiological data on chemical effects were coded under 'epidemiological data to characterize hazards');
(ii) Development of descriptive themes by grouping and sequencing code concepts logically within the risk assessment and management framework (e.g., epidemiological and animal data were classified under the subtheme 'data collection through multiple sources' as part of 'hazard characterization');
(iii) Generation of analytical themes that interpret the findings beyond the specific data, connecting themes to address the review questions by identifying key principles for future guideline development.

Results

Search results

The outreach yielded a response rate of 60% ($n = 47$) from 19 out of 27 EU member states. A third of these responses ($n = 16$) pointed towards their national transposition of the EU directive, providing no additional information. Another 11 documents were generalized on pregnancy legislation with limited information on chemical hazards. Next, five more documents provided detailed information on chemical hazards but contained limited or no information on reproductive health. Lastly, five information leaflets for specific occupations were received and two more were duplicates of other documents we received. These were excluded as they did not add information beyond the directive. An overview of the replies from the outreach to the OSHA focal points and ICOH national secretaries is presented in Supplementary file 1.

As shown in the PRISMA flow diagram in Fig. 1, 973 records were collected through the literature search, making for a combined 1,020 records including the outreach. Nine records met the inclusion and exclusion criteria: eight from outreach and one from the literature search.

Five member states contributed documents that matched the inclusion criteria, and a sixth was added through the literature search. Table 2 provides descriptive information on the nine included documents.

Thematic synthesis results

Descriptive themes

Descriptive themes on hazard identification and characterisation Most guidelines recommend a broader perspective beyond the annexes of the Pregnant Workers Directive. They also acknowledge the challenges in identifying all hazards related to reproductive toxicity. To mitigate this, the guidelines advocate for the use of supplementary tools, such as checklists and information leaflets for specific professions, to help uncover additional hazards not explicitly covered by the directive.

The primary challenge in hazard characterization often arises from limited or unclear data on hazards to pregnancy, necessitating reliance on conclusions drawn from

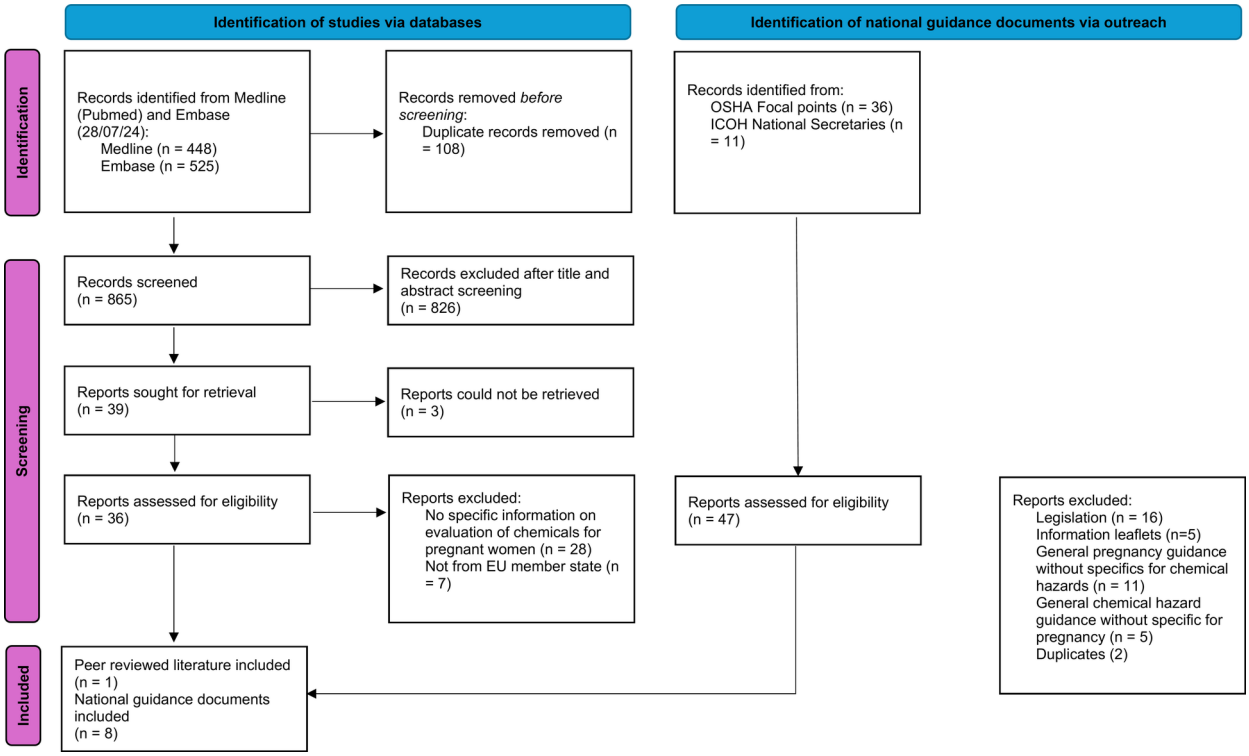

Fig. 1 PRISMA flow diagram of search results and outreach

Table 2 Included documents for the analysis

Document ID	Country	Title (translated, original title in reference)	Authoring organisation	Year
1	Denmark	Chemical instruction pregnancy [16]	Danish Society of Occupational Medicine	2019
2	Finland	Pregnancy and exposure at work [17]	Finnish Institute of Occupational Health	2023
3	France	Medical surveillance of pregnant employees exposed to substances toxic to foetal development [18]	French Society of Occupational Medicine	2004
4	Germany	Risk assessment for maternity protection [19]	Federal Ministry for Family Affairs, Senior Citizens, Women and Youth	2023
5	Germany	Maternity protection when exposed to hazardous substances and biological substances [20]	Institute for Occupational Safety and Health of the German Social Accident Insurance	2023
6	Italy	Protection of health and safety of working mothers. Guidelines for the application of the legislative decree 151/01 [21]	Regional workgroup safety and prevention in workplaces– Friuli Venezia Giulia	2009
7	Italy	Protection of health and safety of working mothers. Guidelines for the application of the legislative decree 151/01 [22]	Regional workgroup safety and prevention in workplaces - Modena	2004
8	Italy	Protection of health and safety of working mothers. Guidelines for the application of the legislative decree 151/01 [23]	Regional workgroup safety and prevention in workplaces– Bologna	2004
9	The Netherlands	Guideline pregnancy, postpartum period and work [24]	Dutch Society of Occupational medicine	2018

primary epidemiological, in-vitro, and animal studies. Knowledge on toxicokinetic mechanisms is emphasized in these guidelines, and frequently cited as a key to determine whether a specific chemical is hazardous. An overview of the specific findings and examples on the theme of hazard identification and characterisation can be found in Table 3.

Descriptive themes on exposure assessment and risk assessment The guidelines highlighted the need for including multiple exposure routes, emphasizing the role of biomonitoring as a solution to assess total exposure. However, challenges remain due to the difficulties in performing biomonitoring and exposure assessment, including the need for repeated evaluations and the complexity of interpreting data, e.g. relating to efficacy of personal protective equipment (PPE) and intermittent exposures.

Risk characterization for the general worker usually begins by the comparison of exposure data with occupational exposure limits (OELs). This knowledge enables

Table 3 Descriptive themes on identification & characterization of hazards to pregnancy

Descriptive themes on identification & characterization of hazards to pregnancy	Examples
Identification of hazards	
Every exposure to a hazardous chemical at levels above those of the general population level should be included.	• All chemicals should be included and evaluated for their possible risks to pregnancy; the analysis should not be limited to CMR-substances. • Situations where an (health-based) limit values could potentially be exceeded, for any chemical, should be avoided by the pregnant worker. • Acutely toxic chemicals and those with identified single or repeated exposure organ toxicity were specifically mentioned as warranting additional attention.
Difficulties in identifying all hazards relevant for reprotoxicity were often emphasized.	• Process-generated chemicals require a high level of expertise to identify due to their unpredictable nature and can be easily missed. • Limitations of the safety data sheet (SDS) caused by: o Incomplete or inaccurate data due to lack of study on the toxicity on the substance. o Lack of requirement to provide SDS for pharmaceuticals o Unreliability of information in SDS files due to reliance on manufacturers to provide correct information
The use of lists to identify additional hazards not explicitly included in EU's pregnant workers directive.	• Lists of specific chemicals that should be avoided or are forbidden. • Lists of additional H-phrases, that are not included in the directive, such as acute toxicity. • Groups of chemicals sorted by their use: e.g., lubricant-coolants, solvents. • Checklists or information sheets for jobs or tasks where chemicals hazardous to pregnancy are commonly used.
Characterization of hazards	
Lack of data necessitates the integration of multiple evidence sources.	• Epidemiological evidence from studies in humans. • Data from studies in experimental animals. • Toxicokinetic information can help with determining the applicability of animal data to the human situation.
Importance of toxicokinetic factors in interpretation of evidence for hazard.	• Assessing the ability, or lack there-of, for systemic absorption (e.g. formaldehyde) • Ability to cross the placental barrier (e.g. solvents transfer easily) • Toxic metabolites can be generated (e.g. styrene oxide metabolites) • Increased sensitivity of the foetus caused by toxicokinetic differences (e.g. more efficient binding of carbon monoxide to foetal compared to maternal haemoglobin)
Challenges in deciding whether a chemical represents a hazard.	• Lack of comprehensive studies on the reproductive toxicity of chemicals. • The need to combine and appraise evidence from multiple sources. • Extrapolation of animal data to the human situation. • Assessing the applicability of findings in the scientific literature to the practical occupational context. • Identification of the genotoxic mechanism for carcinogens, as genotoxic carcinogens is considered a hazard for foetal development.

practitioners to define risk levels and evaluate whether modifications of working conditions are needed. For pregnant workers, it is however crucial to understand the origin of and rationale behind OELs. Guidelines stress the need for higher certainty in risk characterization for pregnant workers, often reflected in the application of additional uncertainty factors, such as using 10% of the conventional OEL for certain groups of substances. General principles of risk characterization are emphasized, particularly the notion that exposure is necessary for a hazard to pose a risk for pregnant workers. Table 4 provides further examples of these principles.

Descriptive themes on risk management Most guidelines emphasize that control of exposures in the working environment should prioritize the higher tiers in the prevention hierarchy, such as elimination, substitution and engineering control, before implementing individual measures for pregnant workers. Preventive maternity leave should be considered only as a last resort when no other feasible solutions exist. Specific attention is given to the use of PPE for maternity protection, with a consensus that PPE should generally be avoided for pregnant workers due to the potential for additional risks and its unreliability in reducing exposure.

The guidelines stress the importance of a proactive approach in several areas. First, they emphasize the need for a clear, pre-established plan with a series of actions that are triggered upon the notification of the pregnancy by the worker to the employer. Second, they call for proactive exposure assessments, where data is collected in advance to facilitate faster and more informed decisions when a worker reports her pregnancy. Lastly, all workers should be proactively informed about procedures in the case of pregnancy, as this can speed up notification of the employer and thereby reduce the likelihood of adverse outcomes. Measures must be implemented with caution to avoid causing physical or psychological strain on pregnant workers, such as increased respiratory effort from respirator use or stress caused by having to perform

Table 4 Descriptive themes on exposure assessment & risk characterisation

Descriptive themes on exposure assessment & risk characterisation	Examples
Exposure assessment	
Combining strategies for exposure assessment.	• All routes of exposure should be addressed (inhalation, dermal, oral). • Use of biomonitoring in assessment of the total exposure • Exposure can be estimated/modelled by assessing the used processes, volumes of chemicals used/produced and the physico-chemical characteristics, such as vapour pressure.
Reliable exposure assessment is challenging but necessary to reliably support maternity protection.	• General exposure assessment challenges o Need for multiple measurements to reach adequate certainty about exposure levels. o Judging the protective effect and reliability afforded by PPE. o Intermittent and or (risk of) accidental exposures are hard to measure/predict. • Limitations of biomonitoring o Limited number of available biomarkers. o Difficulties in procuring biomonitoring samples at end of shift/workweek. o Challenges in accounting for synergistic effects of mixtures with individual biomonitoring markers.
Risk characterisation	
Correct interpretation and use of occupational exposure limits (OEL) is essential.	• Understanding their origin and context: was reproductive health considered when the values were set? • Threshold of effects are generally assumed for the dose-response relationships for reproductive toxicants, although some substances may have very low thresholds. • No safe exposure level exists for genotoxic carcinogens or mutagenic substances, even when they have OELs.
Apply best practices of risk assessment.	• Hazards do not pose risks unless there is exposure. • The more serious the hazards, the lower the tolerance for exposure. • Risk assessment should be continuously updated and evaluated in a dynamic risk control system
Specific considerations for determining acceptable risk levels in pregnant workers.	• Application of extra uncertainty factors to OELs were often suggested, e.g. that a level of 10% of the OEL could be accepted. • Exposures levels below those experienced by the general population were generally considered acceptable, e.g. for diesel engine exhaust. • Biomonitoring was often suggested as a means of exposure assessment. • Handling of some toxic chemicals under very controlled circumstances, e.g. use of very limited amounts in a fume cabinet, were considered acceptable in some guidelines. • The precautionary principle was recommended to be used when data about the hazard or exposure is lacking, unclear or unreliable.

tasks the worker is not trained for. Table 5 summarizes the contents of the analysed documents with regards to risk management.

Analytical themes

Two distinct analytical themes were found, both reflecting a fundamental need in evaluation of the risks posed by chemical agents to pregnant women. Below the identified themes are described, reflecting the need for a broad perspective when assessing chemical risks for reproductive health and the increased need for certainty in this assessment, with examples from the analysed documents.

Theme 1: need for a broad perspective The analysed documents suggest the need for a comprehensive approach in terms of 1) the range of hazardous substances that should be considered (beyond those classified as reproductive toxicants), 2) the potential for multiple routes of as well as accidental exposures, 3) inclusion of the period *before* a worker is known to be pregnant in the risk assessment and risk management process, and 4) consideration of the potential adverse socio-economic consequences of maternity protection policies.

The EU Pregnant Workers Directive provides a list of substances and working conditions that must be evaluated or are prohibited for pregnant women. It is specifically stated that the list is non-exhaustive. Several guidelines indicate additional substance groups that should be considered. For example, many solvents are not included in the list provided by the directive, even though their harmonised hazard phrases are often of concern for the unborn child. An overview of these substance groups mentioned in the guidelines, collated through analysis of the relevant codes on risk identification, can be found in Table 6.

> *…account must be taken of volatile chemicals such as solvents, monomers and amines, but also slowly evaporating chemicals such as auxiliary solvents, coalescing agents and plasticizers [16].*

Acute toxicity, while not mentioned in the annexes of the Pregnant Workers Directive, was sometimes

Table 5 Descriptive themes on risk management

Descriptive themes on risk management	Key messages
Follow prevention hierarchy when taking action	
Change working environment before taking individual action.	• If changes to work reduces the risk inadequately, alternative work should be sought. • Only when no alternative work exists should a worker be placed on prophylactic leave. • Protective measures should not lead to discrimination; ensure they are proportional to the risk and adapted to the worker.
Personal protective equipment (PPE) should be minimally relied on when creating a safe environment for the pregnant worker.	• PPE are not always reliable and should only be used when their effectiveness has been proven and use is sustainable for the pregnant worker. • The use of PPE should not in itself pose a risk to the pregnancy, such as in the case of autonomous air respirators.
Proactive risk management	
A plan in case of pregnancy should be in place before a pregnancy even occurs.	• The process should be fully documented and readily available for everyone. • A consultation with an occupational health physician should be included to identify personal risk factors, in the risk assessment process. • The plan should be implemented immediately after notification of pregnancy by the worker.
Exposure data should be collected proactively.	• Some substances require a proactive monitoring approach in the pre-conception stage, such as: • Accumulating substances with long half-lives. • DNA-altering substances.
Inform workers proactively about risks and maternity protection.	• Early identification of pregnancy is essential to reduce time to notification of employer of pregnancy. • Notification procedures should respect the privacy of the worker as these first weeks are a precarious time period.

Table 6 Overview of substance groups mentioned in guidance documents that do not directly fall under Annex I and II of the pregnant workers directive [6]

Substance group	Example
Solvents without CMR classification	Ethylbenzene
Acutely toxic chemicals	Phenol, cyanide compounds
Neurotoxic metals	Aluminium, Manganese
Dusts & fumes	Diesel engine exhaust, welding fumes, industrially produced nanoparticles, passive smoke
Medicine other than antimitotic drugs	Antibiotics
Monomers	Acrylic monomers, isocyanates
Pesticides without CMR Classification	Some carbamates and organophosphates

included in the list of hazard phrases substances should be screened for. Specifically, acute toxicity was included when it was classified as fatal (H300, H310, H330) or toxic (H301, H311, H331).

> *Activities or working conditions for pregnant women are generally not permitted if they are (or could be) exposed to hazardous substances that are classified under the CLP Regulation as… Acutely toxic according to category 1, 2 or 3 (H300, H310, H330, H301, H311, H331) [20].*

When evaluating exposure, it is essential to adopt a comprehensive approach that considers all potential routes of exposure. This involves application of a combination of biomonitoring and environmental measurements to assess the total exposure, as well as consideration of the possibility of accidental or unintentional exposure. In the latter case, the effectiveness of control measures should be assessed. If there is a reasonable chance of unintentional exposure to a substance known to be toxic to reproduction, it is crucial to take this into account when determining the appropriate protective measures.

> *The injection or infusion of cytotoxic agents carries the risk of exposure through accidental leakage or splashes. Pregnant workers should not perform these tasks unless a closed system is used that has been shown to effectively prevent leakage of the cytotoxic solution outside the system [17].*

The examined guidelines emphasise the importance of a proactive evaluation of all workplaces for reprotoxic hazards. This proactive approach is crucial because the first trimester is a period that is vulnerable to many chemical exposures, and at the same time, it is during this period the worker becomes aware of the pregnancy, i.e. before any protective measures are implemented. A proactive approach which extends to the time period *before* the conception, is especially needed in case of exposure to agents that accumulate in the worker's body, such as lead and aluminium.

> *To prevent aluminium accumulation in the body, pregnant women should aim to keep exposure below the reference level [for urinary aluminium]. Since aluminium is a highly accumulative agent, it is important to detect potential accumulation early and address the exposure well in advance, when planning a pregnancy [17].*

Finally, this broad perspective can also be extended to the prevention of unexpected negative consequences of maternity protection policies. For instance, work adaptations should align with the worker's skills and needs, not to create frustration or psychological strain. Additionally, it is essential to ensure that the implemented measures do not adversely affect the professional development of pregnant workers or lead to discrimination at the professional level.

> *The focus here is on ensuring that women are not disadvantaged in their professional lives due to pregnancy and breastfeeding and that women's right to make self-determined decisions about their employment is not violated. This improves women's opportunities and strengthens their rights to continue working during pregnancy and breastfeeding without compromising their health and that of their children [20].*

Theme 2: need for certainty The importance of ensuring a high level of certainty when dealing with chemical substances during pregnancy, along with the challenges that this entails, are frequently highlighted in the analysed documents for all phases of the risk assessment and management process.

Identifying all potential hazards is the initial step in risk assessment. However, this is not always a straightforward task. Unreliability of safety data sheets can create an obstacle to a comprehensive hazard identification. Also, identifying reprotoxic process-generated substances, such as certain metal fumes/dusts or combustion products, can be challenging. Moreover, exposure to chemical mixtures can introduce additional challenges for the risk assessment process because the joint reprotoxic effects of many mixtures remain unknown.

> *Occupational exposure often involves the presence of a combination of several substances, and in these cases, it is not always possible to know the consequences of the interactions between the different substances and the possible synergistic effects that the chemical mixtures can produce [22].*

To ensure the safety of pregnant workers in potentially hazardous environments, accurate exposure assessments are indispensable, considering all possible exposure routes. While biomonitoring is frequently regarded as a valuable tool because it considers all of these routes, practical and methodological challenges frequently hinder its implementation. For example, when workers are exposed to solvent mixtures often not all constituents of the mixture can be monitored through biological measurements. Nevertheless, in the exposure assessment also the exposure to the unmeasured constituents has to be taken into account.

> *When drawing conclusions about total exposure based on biological exposure measurements, the evaluation must consider the total exposure caused by the solvent mixture used. This means that the effects of constituents that cannot be measured in a biological sample must also be taken into account [17].*

Characterising risk can be challenging, even when exposure can be reliably determined, because it is often difficult to discern whether the exposure level is safe. Occupational Exposure Limits (OELs) do not always take adverse reproductive effects into account, particularly in case of older limit values or newly introduced chemicals. The inability to determine, with certainty, whether a particular limit value is protective against reproductive effects adds to the level of uncertainty.

> *Currently, occupational exposure limit values only consider the effects on reproduction when the product has been tested for this effect. For the limit values established in previous years, it is not certain that this effect has been considered. Hence the need for a safety factor justified by the severity of the effect on foetal development [18].*

The need for certainty becomes apparent once more in choosing the right risk management strategy. PPE is typically viewed as the "last line of defence" for managing risks in the protection hierarchy. However, during pregnancy, this is taken a step further, as PPE is deemed too unreliable and therefore not considered an option.

> *Since personal protective equipment never provides complete protection, tasks in which exposure and risks remain high despite other risk management measures should not be carried out by pregnant workers [17].*

Discussion

This paper aimed to examine the guidance documents on implementing risk assessment and management for pregnant workers related to chemical exposures in EU member states, to provide overview of their content and to identify key principles for the development of new guidelines. Peer-reviewed literature yielded limited findings, identifying only one document. Outreach to EU ICOH national secretaries and EU OSHA focal points achieved a 60% response rate, producing a diverse range of documents. However, only eight met the inclusion

criteria, as many merely transposed content from the Pregnant Workers Directive or its annexes without offering additional practical guidance for implementing this legislation.

The scope and target audience of the analysed guidelines varied significantly. Notably they lacked coverage of key topics such as preconception exposures, the impact of paternal exposure, fertility issues, and outcomes related to early pregnancy, including miscarriage. The available information revealed the complex nature of the subject and highlighted the need to adopt a broad perspective when assessing occupational reproductive risk associated with exposure to chemical substances. It also emphasized the challenges involved in reaching sufficient certainty to allow pregnant workers to safely work with chemicals.

Limitations & strengths

The primary limitation of this study stems from the relative low number of documents available for analysis, suggesting that there might have been documents missed in this analysis. The available documents were highly heterogeneous in scope, target audience, and level of detail, rendering it impossible to systematically appraise guideline quality. Despite these limitations, we believe our analysis reflects the current state of the field and highlights the difficulties faced in assessing reproductive health risk in the occupational context, as our outreach had 60% response rate and represented 19 countries.

To the best of our knowledge, this is the first time a synthesis of guidance documents on this topic in the EU has been conducted. Our analysis confirms the lack of available guidelines that was indicated in the EU-OSHA report [1] and provides two key principles for developing new guidelines: the importance of adopting a broad perspective and the need to provide support in managing uncertainty.

Broad perspective

Recent literature calls for a broad approach in safeguarding reproductive health in the occupational setting [11, 25, 26]. However, current legislation still focuses primarily on pregnant workers after they notify their employer, neglecting exposures during preconception and the earliest stages of pregnancy. This gap may leave both parents and the unborn child inadequately protected before official disclosure. Several chemicals may harm fertility [1]. Paternal firefighting has been associated with elevated risk of birth defects [27] and welding with increased asthma risk in the offspring [28]. However, many unknowns remain to be clarified for paternally mediated developmental toxicity [29].

These findings do however make a case for a broader approach with shift of focus from protection of pregnant workers to protection of reproductive health for all. Interestingly, the American College of Occupational and Environmental Medicine devoted significant attention to the collection of paternal exposure data in their 2016 guidance document on reproductive and developmental hazard management [30], this was, however, not reflected in any of the analysed European guidance documents.

The current form of maternity protection legislation has been described as *differentiated protection* [25]. Apart from the lack of preconception protection, it raises potential concerns of discrimination as hiring managers may perceive women of reproductive age as higher-risk workers due possible future pregnancies [31] and accompanying costs and inconveniences that apply to male workers to a lesser degree. In contrast, a *unified protection approach* would provide protection for reproductive health for all workers by developing regulations and limit values, sufficient to protect also the most vulnerable group(s).

Important steps have been taken to increase reproductive health protection in the EU with the inclusion of effects to reproduction in (what is now called) the Carcinogens, Mutagens and Reprotoxic substances Directive (CMRD) in 2022. This represents a shift towards primary risk reduction for all workers, and a step towards a unified protection approach [8]. However, only chemicals classified for reproductive toxicity in category 1, not 2, are included. A transition towards a more comprehensive "*Reproductive Health Directive*" is needed, with end-to-end coverage, outlining how workers of child-bearing age should be protected, monitored through health surveillance and supported in the case of potential work-related adverse reproductive outcomes.

Need for certainty

Uncertainty in the risk assessment of reproductive hazards can originate from lack of knowledge on the 1) hazardous properties of a compound, 2) dose-response relationship (and consequently on presumed safe levels of exposure), and 3) exposure of the workers.

The uncertainties identified in the guidelines could, to some degree, be overcome by implementing the precautionary principle, enabling decision-makers to adopt precautionary preventive measures when the scientific evidence is uncertain. This principle, though widely accepted and applied in the field of health and safety, has been controversial in the wider scientific community [32], because of the diverse and ambiguous definitions of 'scientific uncertainties', paradoxically leading to uncertainty as to when it should be applied.

Limit values offer essential guidance for practitioners in addressing these uncertainties, yet they are often lacking. Two types of OELs are available within the EU, indicative OELs for chemicals that fall under the Chemical Agents

Directive, and binding OELs when the CMRD applies [33]. Binding OELs take into account the socio-economic impact in the setting of limits. Indicative OELs are purely health-based, leaving it to national authorities to address non-health-related considerations. In theory, reproductive toxicants should receive binding OELs. This is far from reality, as number of existing and new chemicals overwhelms the European Chemical Agency's capacity to generate scientific reports as basis for OEL setting.

To address this issue, Worker Derived No-Effect Levels (wDNEL) should be set by the REACH registrants. wDNELs are health-based exposure levels at which effects are not foreseen to occur. Unfortunately, many substances with harmonised classifications as reproductive toxicants lack both wDNELs and national OELs [34]. Even when set, it is often unclear whether a specific intention is to protect against reproductive toxicity. Furthermore, a wide variability between wDNEL and OEL values exists and is most likely due to differences in the methodologies used to establish OELs and wDNELs, such as the level of risk that is deemed acceptable. No specific level of risk has been set by REACH, raising concerns about their level of protection [34, 35].

Finally, the potential for reproductive toxicity is simply not known for many substances [36]. Under REACH, the required reproductive toxicity data depends on the registered tonnage level [37]. Only for substances marketed at tonnage levels above 100 tons/year/company, effects on fertility and the unborn child are more likely to be detected (due to the obligation to perform a 90-day repeated dose study and a prenatal development study) [35]. This contrasts with evidence from in silico screening of a large number of REACH-registered substances indicating that a significant proportion (11.5%) of substances may be harmful to reproduction [38]. A recent study indicated that only 19% of the substances registered under REACH have comprehensive health-related datasets [39]. Given the high costs and challenges of reproductive toxicity testing, this situation is likely to be more pronounced for reprotoxic hazards.

Taken together this creates an environment where it is very difficult for health and safety practitioners to assess and manage reproductive risks with any degree of certainty. The system used by the German Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area, the so-called MAK commission, offers a potential solution by using a four-tiered notation for reproductive toxicants [40]. Substances in group A have unequivocal evidence of damage to the unborn child in humans at the OEL. Group B substances are suspected developmental toxicants, so damage cannot be excluded if pregnant women are exposed at the OEL. Group C includes chemicals for which damage to the unborn child is unlikely at the OEL. Finally, group D is used for substances where the toxicological data base is inadequate categorisation into one of the other groups [40]. This creates transparency about the level of certainty regarding the protection against reproductive effects for each OEL.

Such a system is highly useful for practitioners, as it assists in determining when and to what extent the precautionary principle should be applied. Future research ought to further investigate this approach, offering practitioners clear guidance and practical recommendations for handling various situations. Given that such guidelines will likely involve making decisions that go beyond the purely scientific, it is essential they are developed in collaboration with stakeholders. Central to this discussion will be the determination of an 'acceptable risk' level, and how scientific uncertainty could be handled in this regard, for reproductive health outcomes.

Conclusion

In conclusion, this study examined guidance documents from EU member states on how to protect pregnant women handling chemical substances at work. A minority of EU member states had guidance documents available specific to the subject that extended beyond the information in the EU directive on pregnant workers. Through qualitative thematic analysis, two primary guiding principles with policy implications were identified. Firstly, the directive's exclusive focus on pregnant workers might not ensure adequate protection for reprotoxic hazards and may have unintentional discriminatory effects; thus, a unified approach that emphasizes safeguarding reproductive health for all workers might be a more effective solution. Secondly, there is a strong need for certainty in an environment where it is challenging to achieve. Therefore, further strengthening the REACH risk assessment process for reprotoxic hazards is necessary. This process should, among others, include establishing health-based limit values for reprotoxic substances or indicating the reliability of limit values in protecting against reproductive effects, thereby enabling practitioners to apply the precautionary principle judiciously.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12995-025-00456-7.

Supplementary Material 1. Outreach overview. An overview of the replies from the outreach to the OSHA focal points and ICOH national secretaries, including links to online locations where possible.

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Authors' contributions
TC was responsible for conceptualisation, data collection, data analysis and interpretation, drafting the article, revisions and final approval of the version to be published. KSH aided with critical revisions of the article and final approval of the version to be published. SR supported with data analysis and interpretation, drafting the article, critical revision of the article and final approval of the version to be published.

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Data availability
The guidance documents used and analysed during the current study are available in the supplementary material or from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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