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Emissions of noxes in the case of welding in shielding gases: a systematic literature review

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Abstract. The paper presents the results of a systematic review regarding emissions of noxes in the case of welding in shielding gases. For this paper it was used The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) published in 2009. A total of 65 academic papers retrieved from the ScienceDirect Freedom Collection, Elsevier database, Web of Science - Core Collection, Clarivate Analytics, Scopus, SpringerLink Journals databases were identified and analysed. The main objectives of this review were to answer the following questions: (1) What are the major health issues related emissions of noxes in the case of welding in shielding gases? (2) What are the measures of control for the fumes and gases? The search was conducted in January 2023. The results were organized into two major sections. The first include information on major health issues associated with welding noxes. The second contains studies thought to be relevant on measures of prevention and control.

Keywords: *welding, noxes, prevention, control*

1.Introduction

A systematic review is a research methodology used to answer a specific research question by identifying, evaluating, and synthesizing all available evidence from relevant studies. Systematic reviews are often used to provide a summary of existing research on a particular topic, to identify gaps in the literature, and to provide recommendations for future research.

Systematic reviews are essential not only for researchers, policy makers and other decision makers but also for students, who without them, would be confronted by an overwhelming volume of research on which to base the „state of the art" chapter in their thesis. The methods and results of systematic reviews should be reported in sufficient detail to allow users to assess the trustworthiness and applicability of the review findings.

To conduct a systematic literature review on welding fumes and gases, we started by defining the research question and developing a protocol that outlines the methods to be used. This would include identifying relevant search terms and databases to be used, as well as inclusion and exclusion criteria for studies to be included in the review.

For this paper it was used The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA). The PRISMA has been designed primarily for systematic reviews of studies that evaluate the effects of health interventions, irrespective of the design of the included studies. However, the checklist items are applicable to reports of systematic reviews evaluating other non-health-related

interventions (for example, safety and health, occupational safety), and many items are applicable to systematic reviews with objectives other than evaluating interventions [1]. The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement, published in 2009 (hereafter referred to as PRISMA 2009) was designed to help authors prepare transparent accounts of their reviews, and its recommendations have been widely endorsed and adopted.

2.Research Methodology

To perform a systematic review of the literature it was used The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA). The Preferred Reporting Items for Systematic reviews and Meta-Analyses PRISMA method includes three phases, i.e., literature search, articles selection, and data extraction.

To ensure the quality and reliability of data, only journal papers written in English, Romanian and French were considered; reviews, textbooks, doctoral dissertations, letters, and conference papers were also included in this study. In order to obtain comprehensive and reliable results related to the subject of noxes, a two-level keyword structure shown in Table 1 was adopted. The time span of the literature search was restricted to 1980–2022.

Table 1

Main keywords	Subordinate keywords
Emissions of noxes in the case of welding in shielding gases	GMAW MIG MAG welding fume airborne particles from welding operations welding aerosol chemical analysis of welding fume particle welding fumes exposure health issues related to welding

A total of 66 academic papers retrieved from the ScienceDirect Freedom Collection, Elsevier database, Web of Science - Core Collection, Clarivate Analytics, Scopus, SpringerLink Journals databases were identified and analyzed. The main objectives of this review are to answer the following questions: (1) What are the health issues related to emissions of noxes in the case of welding in shielding gases? (2) What are the measures of control for the fumes and gases?

The Preferred Reporting Items for Systematic reviews and Meta-Analyses PRISMA is published as a suite of three papers: a statement paper, the PRISMA abstract checklist, and the flow diagram [3]. Because we were carried out the review as a members of a wider team, we consulted the other members of our team regularly in order to prevent misunderstandings. Different people may use the terminology in different ways depending on their geographical location or profession.

For the first step, following the flow diagram, once the topic has been clearly defined, there were set up **limits** by language and date of publication. Then there were defined **the search terms** by running a couple of wide searches on the most commonly used databases in our subjects. We found some relevant articles and read through them highlighting key words or phrases. Then we used them as the basis for our search strategy. We made a list of the core terms and any synonyms and spelling variations. Because the most precise way to search any database was to use the words included in the thesaurus for the individual database, as new articles were added to a database, they were indexed using a list of approved keywords or thesaurus. This is why we always searched one database at a time - remembering that thesauri vary from database to database. Even natural language words can vary in the way they are used. Using this type of search produced very focused results. Also, because the research protocol required to widen out the search to ensure that is not miss out any research and many grey literature sources and

search engines do not use thesauri, we used a combination of terms, alternative keywords when searching.

To complete the PRISMA diagram it was printed out a copy of the diagram to use alongside our searches. It is most efficient to search databases individually, so we printed out a copy for each database searched, plus a copy for the totals.

For each database we entered each key search term individually. This included all our search terms. We combined all the search terms in the different combinations using Boolean operators like AND OR as appropriate. We applied all our limits (such as years of search, full-text only, English language only and so on). Once all search terms have been combined and we have applied all relevant limits, we obtained a number of records or articles and entered this in the top left box of the PRISMA flow chart for each database. Because we have searched databases individually, we added all the 'records identified' up and fill this total number in the PRISMA flow diagram. This process of adding up the number of records in individual database searches to a total was repeated at each step.

For the articles identified through other sources than databases (like manual searches through reference lists of articles found, or search engines like Google Scholar), we entered the total number of records in the box on the top right of the flow diagram.

To avoid reviewing duplicate articles, it was removed manually any articles that appear more than once by going through all the records or articles found in the database. The number of records left after the removal of the duplicates was entered in the second box from the top.

The next step was to add in the number of articles that we have screened. This is the same number as we have entered in the duplicates removed box.

In this step we screened the titles and abstracts for articles which were relevant to our research question. Any articles that appeared to help us provide an answer to our research question it was included. The number of articles excluded based on this screening process it was recorded in the appropriate box (next to the total number of screened records) with a short reason for excluding these articles.

Then it was subtracted the number of excluded articles following the screening phase from the total number of records screened and entered this number in the box titled "Full-text articles assessed for eligibility". The full text for these articles was reviewed for eligibility.

We reviewed all full-text articles for eligibility to be included in the final review. At this stage we checked in our guidelines and with our supervisor, how many articles we should be left with. The number of articles that were excluded at this point was entered in the box titled: Full text articles excluded and we write in a short reason for excluding the articles (it may be the same reason used for the screening phase).

The final step was to subtract the number of excluded articles or records during the eligibility review of full-texts (step 8) from the total number of articles reviewed for eligibility. The number obtained may varied depending on the type of assignment and it was entered in the final box.

3.**Results and discussion**

The search was conducted in January 2023. The results were organized into two major sections presented below. The first include information on major health issues associated with welding noxes. The the second contains studies thought to be relevant on measures of prevention and control.

For the category health issues associated with welding noxes a total of 1500 papers were initially derived based on the above search strategy (fig.1). After deleting duplicate items, 1260 records were remained for further analysis. In the second phase, we reviewed titles, abstracts, and whole text of the remaining articles to exclude unrelated ones. This research is only focused on the papers dealing with major health issues associated with emissions of noxes in the case of welding in shielding gases. Finally, 34 articles were considered within the scope of our inclusion criteria after title, abstract, and full-text.

For the category measures of prevention and control associated with welding noxes a total of 1745 papers were initially derived based on the above search strategy (fig.2). After deleting duplicate items, 1100 records were remained for further analysis. In the second phase, we reviewed titles, abstracts, and

whole text of the remaining articles to exclude unrelated ones. This research is only focused on the papers dealing with major health issues associated with emissions of noxes in the case of welding in shielding gases. Finally, 32 articles were considered within the scope of our inclusion criteria after title, abstract, and full-text.

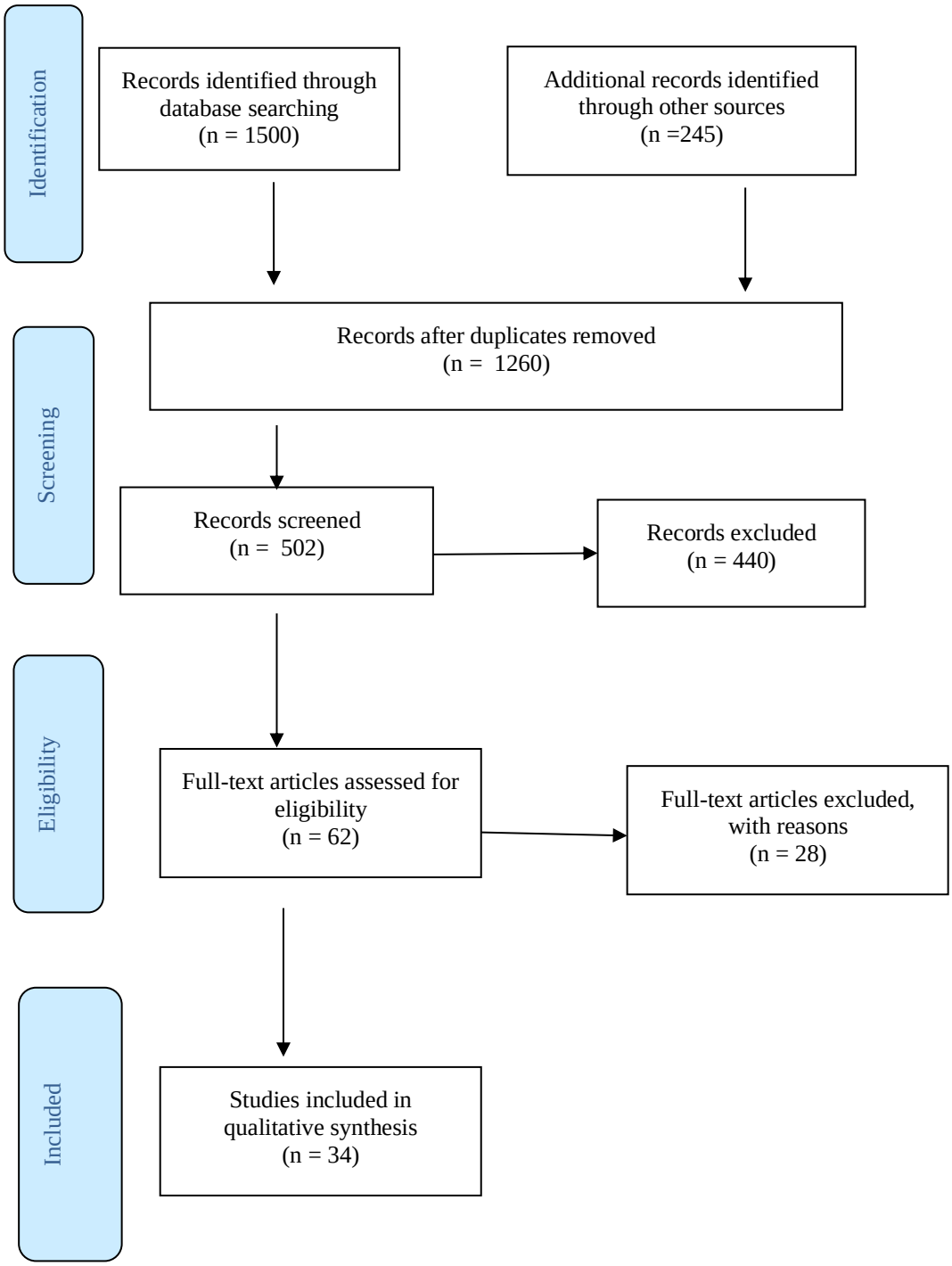

Figure. 1. PRISMA flow diagram for category „health issues associated with welding noxes„

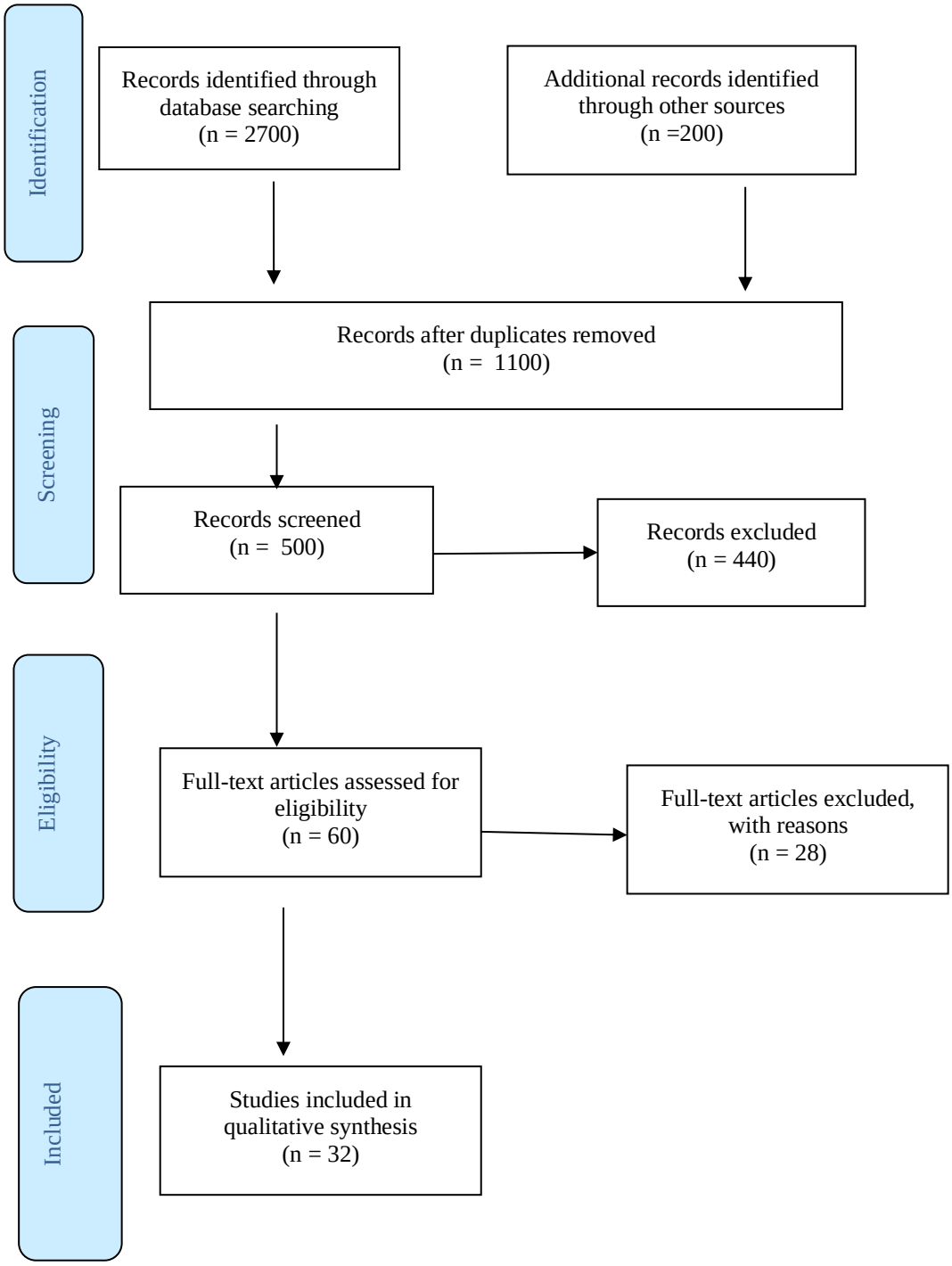

Figure 2. PRISMA flow diagram for category „measures of prevention and control"

3.1 Major health issues associated with welding noxes

Any material is a potential source of fume when heated to high temperatures. The process of heating the base metal with the electrode above its boiling point can evaporate part of those components to the atmosphere. The welding fume is a result of the condensation of the gases and vapour mixture created during the welding. Those fumes are composed by a complex micron and sub-micron size mixture of

fine solid metal particles that may contain metallic oxides, silicates, and fluorides. Those particles will be suspended in the air until some eventual force (air movement, gravity, or some electrical fields) will settle them down.

The suspended particles in the atmosphere can be easily inhaled and can penetrate deeply into the respiratory tract, being carried inside to inner parts of the lungs, causing severe damage to the body. If the welders have been exposed to those particles over time, it can be extremely harmful to their health, causing severe respiratory, neurological, and reproductive damage to their organism. Knowing how to decrease and control the emission levels of welding fumes by selecting the right process parameters and operating conditions can be very useful for the workers at workplace. For this reason, accurate fume formation data is necessary to understand better the welding mechanisms that can reduce the fume emissions, to create a more sophisticated fume control strategy.

The findings from our literature survey on the major health issues associated with welding are reported to be i) respiratory problems (caused by particulate emission from the welding source) ii) skin cancer (caused by UV emitted from the welding arc) iii) metal fume fever (by exposure to Al_2O_3, ZnO, and Fe_2O_3 emanating from the welding process). [2]

It is very important to specify that, in 2018, welding fumes were classified as "carcinogenic to humans" by International Agency for Research on Cancer 2018. Welding fumes are a mix of fine solid particles, including metal oxides, silicates, and fluorides that are released during welding. IARC based this assessment on "sufficient evidence" from the >50 epidemiologic studies on the effect of exposure to welding fumes (generally assessed indirectly through welding process or material, branch of industry, occupation, job title, job task, expert assessment or self-report) on lung cancer [3]. We also found four published meta-analyses reporting on the effect of welding fume exposure on development of lung cancer [4], [5], [6], [7].

3.2 Measures of control

Welding is regarded as being a hazardous activity, requiring measures to be in place to minimise the risk. Welding fume is an important topic that has been studied widely over many years and public awareness of the hazards of fume from arc welding processes has increased significantly recently. The control of fumes and gases can be done by enclosure and local exhaust ventilation (LEV); respiratory protective equipment (RPE) may also be necessary in certain circumstances, in particular in confined spaces.

Increasing attention must be paid to the investigation and development of consumables with minimum fume emissions and for the selection of process parameters which minimise emissions because the adverse health effects can be effectively controlled by reducing the fume emission, evolved gas emission, and harmful radiations at the source itself. From the systematic literature survey, it was found that reactive metal addition, nano-calcite addition, nano-alumina addition, titania addition, and composite coating can reduce these harmful effects to the welders. The addition and coating of reactive metals can bring tremendous changes in fume formation rate (FFR) and hexavalent chromium formation. Other measures of control found in literature are: selecting welding mode (voltage) to minimise spatter; selecting shield gas to facilitate smooth metal transfer, using modern power sources allowing good control of electrical parameters, high purity wires including surface (avoid Na lubricants), optimising oxygen in primary shield gas [8].

4.**Conclusions**

The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) was a great help for authors to prepare transparent accounts of their reviews. Systematic reviews are essential not only for researchers, policy makers and other decision makers but also for students, who without them, would be confronted by an overwhelming volume of research on which to base the „state of the art" chapter in their thesis. With the help of PRISMA the methods and results of systematic reviews can be reported in sufficient detail to allow users to assess the trustworthiness and applicability of the review findings. For this paper it was used The Preferred Reporting Items for Systematic reviews and Meta-Analyses

(PRISMA) published in 2009. A total of 65 academic papers retrieved from the ScienceDirect Freedom Collection, Elsevier database, Web of Science - Core Collection, Clarivate Analytics, Scopus, SpringerLink Journals databases were identified and analysed. The main objectives of this review are to answer the following questions: (1) What are the health issues related emissions of noxes in the case of welding in shielding gases? (2) What are the measures of control for the fumes and gases? The search was conducted in January 2023. The results were organized into two major sections. The first include information on major health issues associated with welding noxes. The the second contains studies thought to be relevant on measures of prevention and control.

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